Reliability

可靠性 Confiabilidade

موثوقية Fiabilité Affidabilità

信頼性 Αξιοπιστία Zuverlässigkeit

Confiabilidad Niezawodność Надежность

XFMEA®

RCM++®

START

THE SYNTHESIS PLATFORM®

Use with: Xfmea_RCM10_QuickStart_Rev1.rsgz10

Quick Start Guide

XFMEA®

Version 10

RCM++®

Version 10

ReliaSoft®

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Xfmea/RCM++ 10 Quick Start Guide

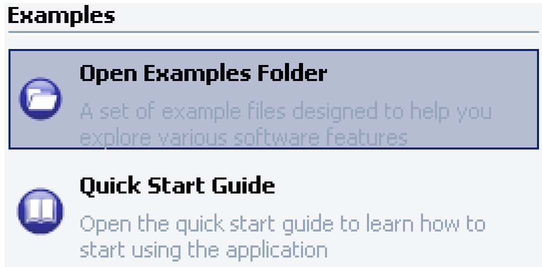
1

Thank you for your interest in ReliaSoft's Xfmea and RCM++ software tools. This quick start guide has been designed to help you explore many of the software's key features by working through step-by-step instructions for some practical application examples.

In order to demonstrate a variety of different applications for the tools available in Xfmea and RCM++, this guide asks you to imagine that you are the leader of a team of engineers working through the Design for Reliability (DFR) and maintenance planning activities for a new single light pendant chandelier. Please note that the sample analyses provided are fictional and intended for demonstration purposes. They are not intended to be realistic. Furthermore, note that although this guide attempts to introduce you to some of the most frequently used tools, Xfmea and RCM++ support many other methods and applications. Within the software, you can choose **File > Help** to access a wide array of resources that will help you explore other capabilities.

In addition to this introduction, the following chapters are presented in this guide. Note that the examples in chapters 3 through 6 can be performed in either Xfmea or RCM++. RCM++ is required for the examples in chapters 7 and 8.

The quick start repository that is included with the software, (called "Xfmea_RCM10_QuickStart_Rev1.rsgz10") contains sample projects that show the examples in this guide at various stages of completion. To access this file, choose **File > Help**, click **Open Examples Folder**, then browse for the file in the **Xfmea** or **RCM** sub-folder.



Tip: To preserve the integrity of the shipped example files, the software creates a copy of the file each time you access a repository in the Examples folder. The copy has the same name as the original file and is saved in the default documents folder for your computer (e.g., My Documents\ReliaSoft\Files). Use the copy to work on the example projects and save your changes. Any changes you make in the copy will not affect the original file.

When applicable, the instructions in this guide will refer to a completed project in the quick start repository. While reading any example in this guide, you have the choice to:

- Examine how it was completed in the sample project.
- Follow the instructions to perform most of the analysis steps on your own.

IMPORTANT: Note that it may sometimes be necessary to modify the data in the quick start repository to fit updated instructions or new examples in the latest printing of this quick start guide. This printing of the guide was designed for use with **Xfmea_RCM10_QuickStart_Rev1.rsgz10** (where _RevX indicates the database revision). If you try to use a different database revision, the sample projects may not exactly match the instructions printed here. 1) If this guide is older than the latest database revision installed on your computer, you can choose **File > Help > Quick Start Guide** to download the latest printing. 2) If this guide is newer than the latest database revision installed on your computer, you can choose **File > Help > Check for Update** to download the latest software service release.

Working in Xfmea/RCM++ 2

This chapter provides some general information about the Xfmea/RCM++ interface that may be helpful to understand before you start working through the examples that begin on page 9.

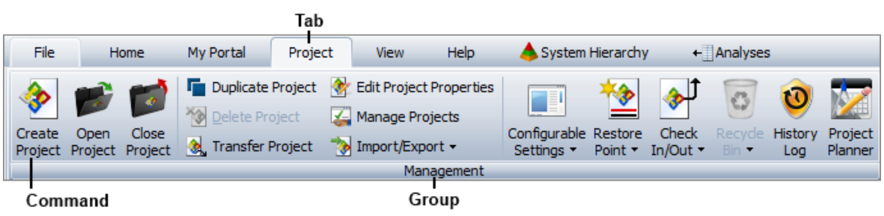
The step-by-step instructions in the chapters that follow will assume that you're generally familiar with these major aspects of the software interface.

In this chapter

- ✓ Ribbon commands
- ✓ Customization
- ✓ System and analysis panels

References to Ribbon Commands

In this guide, ribbon commands are given in **Tab > Group > Command** order. For example, to create a new project, you would choose **Project {*the tab*} > Management {*the group*} > Create Project {*the command*}**. In most cases, the command icon is also provided.



Extensive Customization Options to Fit Your Particular Process

There are many flexible capabilities to customize Xfmea/RCM++'s interface and reports to meet the specific needs of your organization.

The Profiles/Libraries Manager allows authorized users to manage predefined sets of configurable settings in a *library*. This library will contain one or more *profiles* that can be used to set all of the configurable settings for a particular type of project. For example, you might have one profile for design FMEAs and another profile for process FMEAs; or for RCM++ users, another profile for RCMs.

The simplest way to set the properties for a particular project is to choose a profile from the drop-down list on the General tab of the Project Properties window. It is important to note that the settings are **copied** from the active library to each project, **not linked**. If you change a predefined profile in the active library, the settings for existing projects will not be updated automatically. However, you can easily apply the latest settings to an existing project by opening the Project Properties window and choosing the profile again from the drop-down list.

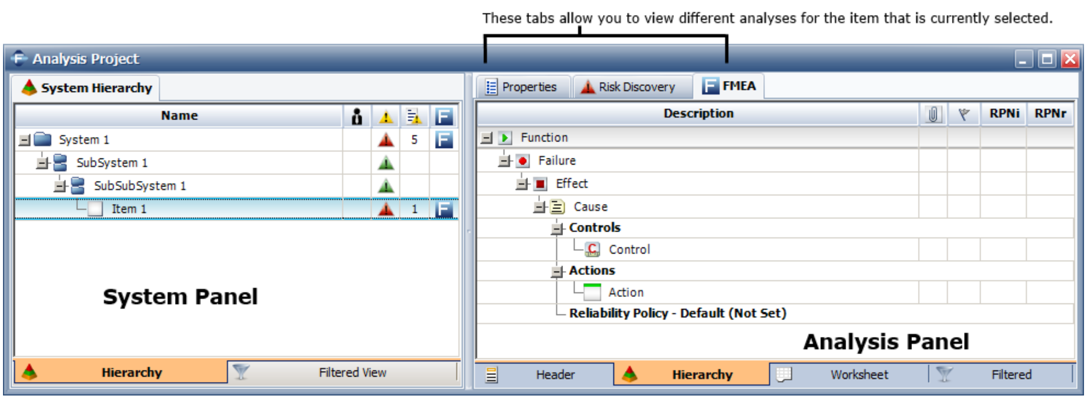
You also have the option to edit configurable settings directly from within the project. If you edit the individual project's settings on the Configurable Settings tab of the Project Properties window, the changes affect the current project only and do not automatically update the profile. If you want to use the current settings from a particular project to create a new profile in the active library, click the **Send Settings to Library** button.

Note: In this guide, the examples use predefined profiles that are shipped with the software. For your own implementation, it is likely that you (or someone else in your organization) will determine which profiles meet the specific needs of your organization and configure the active library so these "approved" settings are the only options available when users create new analysis projects.

System Panel and Analysis Panel

In Xfmea/RCM++, the information in a project is displayed in two convenient panels. The first panel (called the *System panel*) allows you to build single or multi-level configurations that contain the item(s) you plan to analyze. The second panel (called the *Analysis panel*) contains all of the properties and analyses for the item that is currently selected. These panels can be displayed side-by-side or one on top of the other.

For example, the following picture shows the panels side-by-side with "Item 1" currently selected in the System panel on the left. The Analysis panel on the right shows the tabs at the top of the panel for the item properties, risk discovery analysis and FMEA that has been performed for this item.



Perform Analyses for Any Item in a Large Multi-Level System Configuration

The flexible system hierarchy interface allows you to manage large, multi-level system configurations with as many levels as you need, and any number of items per level. You can fully define the properties for each item (e.g., supplier, part number, expected operating environment, etc.) and perform FMEAs and related analyses at any level within the system configuration (e.g., system, assembly and/or component).

> **Note:** For the simple examples performed in this quick start guide, it is easy to build the system configuration manually using the software interface. For larger configurations, you can import the data from a Microsoft Excel® file, from ReliaSoft's XFRACAS or from another Xfmea/RCM++ project.

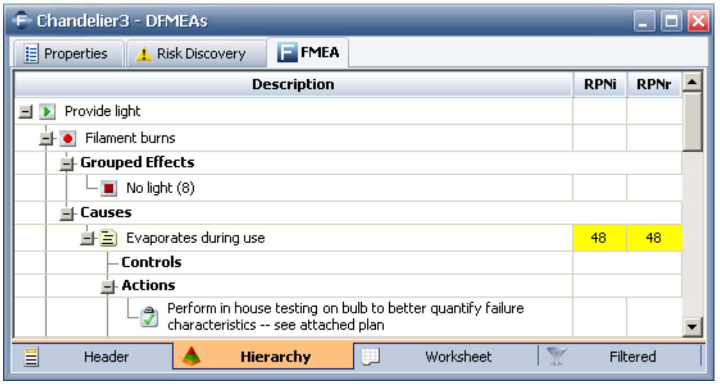
To choose which analysis columns will be displayed on the System Hierarchy tab of the System panel, right-click a column header in the system hierarchy, then click **Customize Columns**. These columns allow you to see at-a-glance which analyses are present for each item.

The columns you choose to display have no effect on the analysis data stored in the project so you can change the preferences at any time. The settings on your computer can be different than the ones that other users have configured on their own computers.

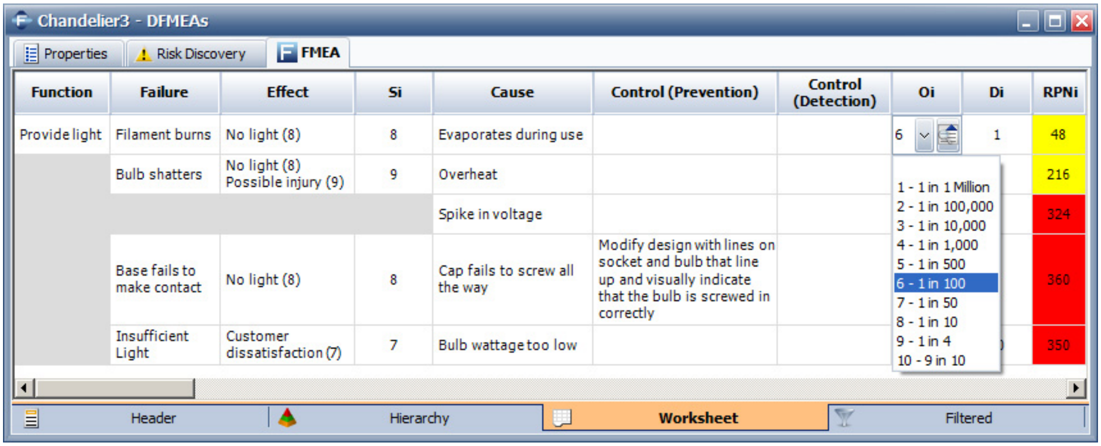
Three Complementary Views of the FMEA Data

The FMEA tab in the Analysis panel offers three complementary views. The analysis information is stored in the database and these views simply present the same data in different ways. You can use the buttons at the bottom of the interface to switch back and forth between the views as needed.

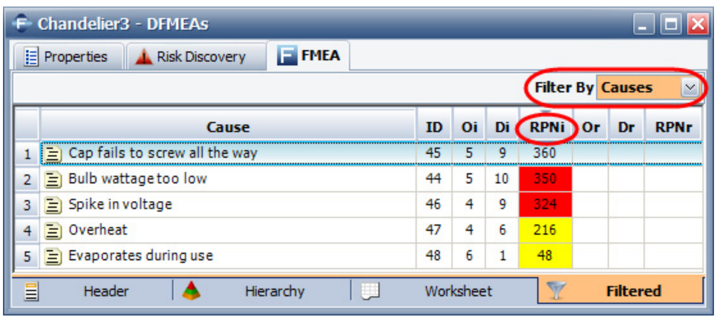
- The **Hierarchy** view tends to be good for viewing a lot of information in a small amount of space. It can be especially useful when copying and pasting data or when scanning the analysis to find a particular section of the FMEA.



- The **Worksheet** view allows you to type directly into the worksheet cells and tab through the analysis as you would in a spreadsheet application such as Microsoft Excel.



- The **Filtered** view presents a sortable list of all records of a particular type. You can choose the record type that you want to view using the **Filter By** drop-down list in the upper right corner. You can then sort the records that appear in this view by clicking a column header. For example, you may wish to see all cause records sorted by initial RPN, as shown below.



Worksheet View vs. Hierarchy View: When many of us think about FMEAs, the first thing that comes to mind is the traditional worksheet with the tabular report format that is found in most published FMEA standards. While this worksheet served us well when the most advanced tools at our disposal were a typewriter and a pocket calculator, it can be an inefficient format for managing large amounts of interrelated data on a computer.

While the worksheet view that mimics the printed layout is available in Xfmea/RCM++ whenever you choose to use it, the more efficient and flexible hierarchy view will be used in the examples in this document.

The Project Planner 3

Design for Reliability (DFR) is a process in which a set of reliability engineering practices are utilized early in a product's design and integrated into the entire product development cycle. It is widely understood that the cost of addressing reliability issues increases significantly as a product progresses through the development cycle (e.g., it is usually much more expensive to provide support for an unreliable product than it is to improve a product's design). Thus, the effective use of DFR can minimize the costs and maximize the benefits of producing a reliable product.

In this chapter

- ✓ Project creation
- ✓ Project plan

The Project Planner, which is available in all Synthesis desktop applications other than MPC, provides flexible tools to facilitate DFR and other reliability-related project planning.

3.1 Creating a Customized Project Plan

You are the leader of a cross-functional team that is responsible for implementing the DFR process for a new single light pendant chandelier that your company plans to produce. Your first task is to establish a project plan for all of the activities that will be performed throughout the chandelier’s development cycle. You decide to use the Synthesis Project Planner so that:

- The information will be readily available to all members of the team.
- You can use the software's action management capabilities to notify team members about their responsibilities and track the completion status.
- The plan can be updated with new information when specific analyses are performed using any of the applications integrated into the Synthesis Platform.

Objectives

- Use Xfmea/RCM++ to create a new project in a Synthesis repository.
- Set the working days and holidays that will be used for project planning throughout the current database.
- Use a template to create a new project plan for the analysis project, and begin customizing it to fit the specific DFR process used within your company.

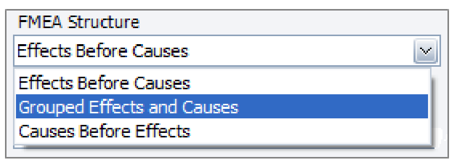
Note: If you want to perform the analysis steps on your own, please create a new project in a new or existing database. If you prefer to examine a completed analysis, you can open the "Chandelier1 - Project Planner" project in the quick start database.

Solution

With the database open, you choose **Project > Management > Create Project** and set the project properties that will be appropriate for both the project plan and for the design FMEAs that your team will later perform on the chandelier's assemblies/components.

For the purpose of this example, you can enter anything you wish for the name, description, remarks, proprietary label and project category. Only the project name is required.

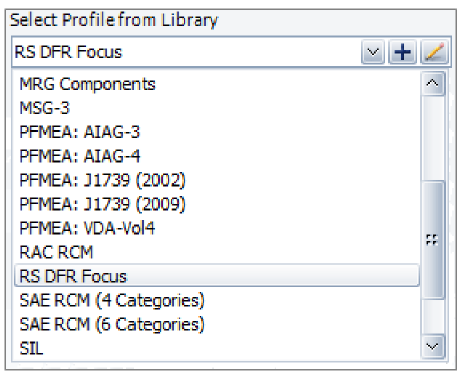
For the **FMEA Structure**, you choose **Grouped Effects and Causes**. This determines how the software will display the effect and cause records in the FMEA hierarchy later in the process.



FMEA Structure: The FMEA structure setting on the General page of the Project Properties window determines how to configure the FMEA hierarchy.

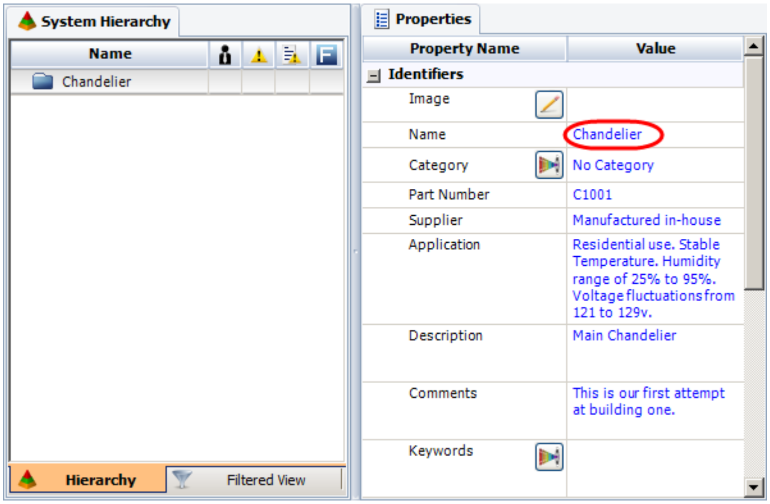
- **Effects Before Causes** displays the causes under the effects so that you can use different severity ratings when calculating the RPN for different causes that are associated with the same failure mode (if it is appropriate in the context of the particular analysis).
- **Grouped Effects and Causes** displays causes and effects at the same level of the hierarchy under the failure mode that they are both associated with. When calculating the RPN, the software will automatically choose the highest severity rating among all of the effects that are defined for the failure mode.
- **Causes Before Effects** displays the effects after the causes, and requires that there can be only one effect record per cause. For example, this may be appropriate for an RCM analysis where the analysts identify functions, functional failures, failure modes (i.e., causes) and then effects.

For **Select Profile from Library**, you choose the **RS DFR Focus** profile that is shipped with the software by default. This copies the predefined field names, rating scales and other settings that will be used in the current project.

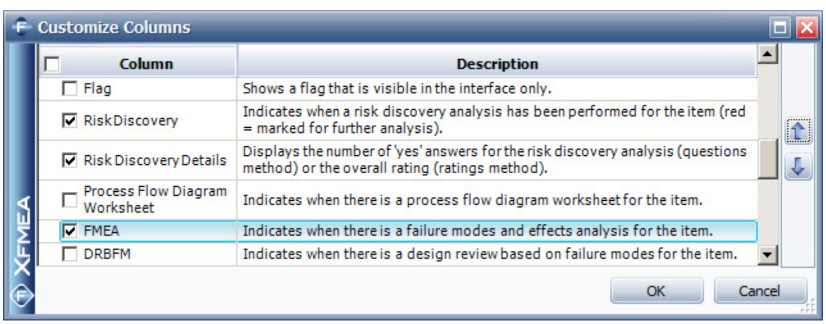


Tip: For your own implementation, it is likely that you (or someone else in your organization) will configure the project categories and profiles library to meet the specific needs of your organization.

When you click **OK** to create a new project, the software automatically adds the first item to the system hierarchy. To rename this item to "Chandelier," you select the item and then type inside the **Name** field of the Properties tab. You also enter additional properties to describe the system, as shown next.



Next, you right-click any of the system hierarchy column headers and choose **Customize Columns**. For this analysis, you choose to enable only the **Risk Discovery**, **Risk Discovery Details** and **FMEA** columns, as shown next. (*Note that you must perform this step even if you are simply examining a completed analysis. These settings are not stored in the database or project. Instead, they are stored per computer/username so any project that you open on this computer will have the same columns displayed at any given time. After you complete the examples in this guide, you can return to this window to configure the workspace to fit your particular preferences*.)

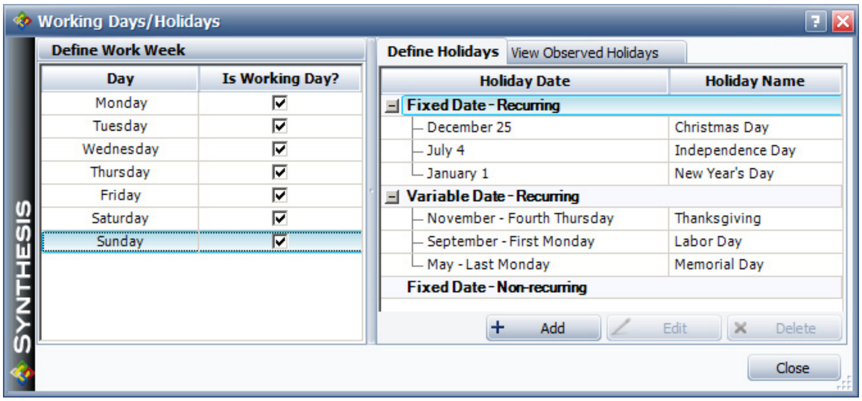


You click **OK** to save your preferences and return to the system hierarchy.

Set the Working Days

Your company is open 7 days a week. To make all days of the week available for project planning, you choose **File > Manage Repository > Working Days/Holidays**.

In the Working Days/Holidays window, you select the check boxes for **Saturday** and **Sunday**, then close the window.



Create the Project Plan

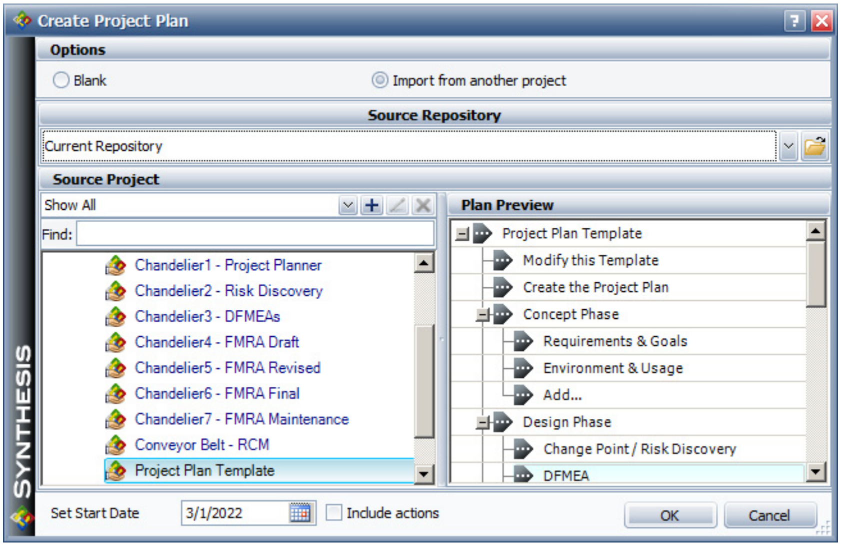
To create the project plan, you choose **Project > Management > Project Planner**.

This creates a new blank plan, but you can save time by importing predefined gates from another existing plan (or predefined template). You choose **Project Planner > Plan > Create Project Plan** to open the Create Project Plan window.

You select **Import from another project** and **Current Repository**.

Note: These instructions assume that you are working from a project created in the Xfmea/RCM++ quick start database (which contains the template used in this example). If you are working in a different database, you can browse for the quick start database or the Project_Planner_Templates_Rev1.rsr10 example database that is installed with the software.

Select “Project Plan Template,” then enter **3/1/2022** in the **Set Start Date** field and clear the **Include actions** check box, as shown next.



Note: To ensure that you will be able to see some of the “status” functionality that is built into the software, this example uses a date that is far in the future. By using a future date, the statuses all show as “Not Started” (rather than “Past Due”), which is more likely to appear in a new plan.

Choose Which Columns Will Display

Next, you right-click one of the column headers and choose **Customize Columns**. For this analysis, you choose to enable only the **Status**, **Planned Start Date**, **Planned Completion Date** and **Actual Completion Date** columns.

Remove Irrelevant Gates

When you are ready to begin customizing the plan, you first remove the gates that are not applicable for the current project. To delete each one, you select the gate and press **DELETE** then click **Yes** to confirm that you wish to proceed. For this project, you delete the following gates:

- Modify this Template
- Create the Project Plan
- All 6 of the placeholder “Add...” gates that are intended as a reminder that you can add additional gates to the plan when applicable.

Remove Gaps in Dates

Removing the "Add..." gates left large gaps throughout the plan. For example, the top-level "Concept Phase" gate is still due on 4/4, but its last sub-gate, "Environment & Usage," is due a week earlier than that. You remove all of these gaps by choosing **Project Planner > Tools > Remove Gaps in Dates**.

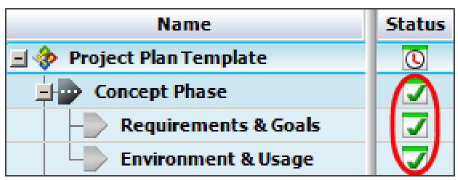
A window will appear asking if you want to remove the gaps and assign precedents to each gate. Since every gate must have an assigned precedent in order to remove all gaps, you click **Yes**.

Enter Completion Dates

Some of the early gates have already been completed, so under the "Concept Phase" gate:

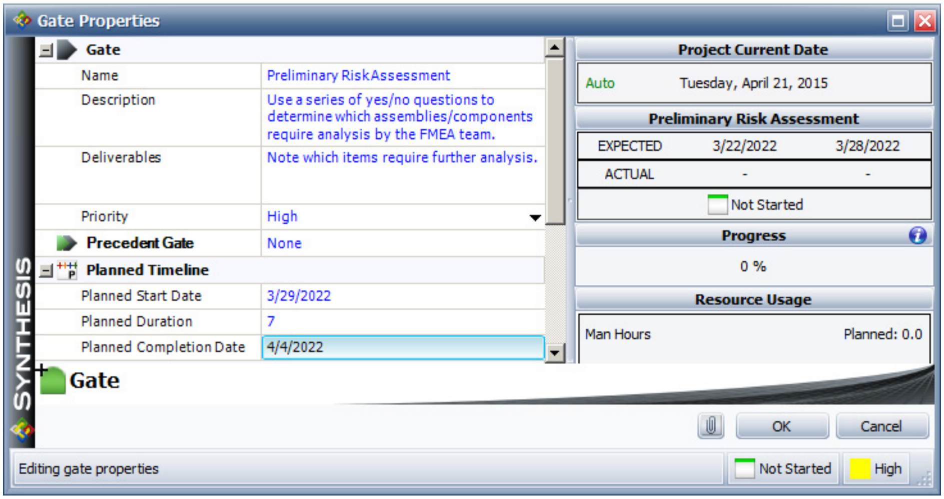
You double-click the sub-gate called "Requirements & Goals" then enter the actual start date (**3/1/2022**) and the actual completion date (**3/10/2022**). When you click **OK** to save the changes, you can see that the Status column now shows that this task has been marked as **Completed - On Time**.

For the sub-gate called "Environment & Usage," you enter the actual start date (**3/11/2022**) and the actual completion date (**3/21/2022**), and save the changes. The entire "Concept Phase" gate now shows as being **Completed - On Time** because all of its sub-gates are marked complete.



Change Start Dates and Durations

Next, under the "Design Phase" gate, you double-click the "Change Point / Risk Discovery" sub-gate and change all of the fields under the **Gate** heading as shown next. Notice that the **Planned Start Date** is set to **March 29, 2022**, which is the date the team will start identifying which items in the chandelier's system configuration should have an assembly- or component-level FMEA performed.



After you click **OK** to save the changes, you see that the new due date for the preliminary risk assessment automatically updates the start date for the DFMEA, and so on down the rest of the sub-gates in this phase.

You then double-click the "DFMEA" gate and change the **Planned Duration** to 21 days as the team expects that creating the FMEAs will not take longer than 3 weeks, rather than the 6 weeks specified in the template. You then close the window and return to the project plan.

Finish Customizing the Plan

Shortening the durations of gates under "Design Phase" left a long gap between the "Design Phase" due date and that of its last sub-gate. To remove this gap, you double-click the "Design Phase" gate and change the planned completion date to **5/23/2022** to match that of "Update DFMEA." Since the duration of "Design Phase" is now shorter, the remaining gates in the plan are automatically updated to begin earlier.

Finally, you again choose **Project Planner > Tools > Remove Gaps in Dates** so that the end date for the project plan matches that of the end date of "Support Phase."

The modified plan is shown next.

Name	Status	Planned Start Date	Planned Completion Date	Actual Completion Date
Project Plan Template		3/1/2022	7/13/2022	
Concept Phase		3/1/2022	3/28/2022	3/21/2022
Requirements & Goals		3/1/2022	3/14/2022	3/10/2022
Environment & Usage		3/15/2022	3/28/2022	3/21/2022
Design Phase		3/29/2022	5/23/2022	
Preliminary Risk Assessment		3/29/2022	4/4/2022	
DFMEA		4/5/2022	4/25/2022	
Compute Baseline Reliability		4/26/2022	5/2/2022	
Reliability Importance Analysis		5/3/2022	5/9/2022	
Reliability Allocation		5/10/2022	5/16/2022	
Update DFMEA		5/17/2022	5/23/2022	
Development Phase		5/24/2022	6/28/2022	
Prepare FRACAS		5/24/2022	5/31/2022	
Component Testing		6/1/2022	6/7/2022	
Accelerated Testing		6/1/2022	6/7/2022	
Subsystem Testing		6/8/2022	6/14/2022	
Reliability Growth Monitoring		6/15/2022	6/21/2022	
Validation		6/22/2022	6/28/2022	
Manufacturing Phase		6/29/2022	7/6/2022	
PFMEA		6/29/2022	7/6/2022	
Support Phase		7/7/2022	7/13/2022	
FRACAS		7/7/2022	7/13/2022	

You will continue to update the plan as your team works through the stages in the process.

System Hierarchy and Risk Discovery

4

One of the early steps in any DFR process is to identify the assemblies and components that comprise the system. Xfmea/RCM++ makes it easy to import information from an outside source (e.g., "Bill of Materials") or build the configuration directly within the software. Once the assemblies and components have been identified, the team may wish to perform a *preliminary risk assessment* (for a new design) or a *change point analysis* (for a new version of an existing design) in order to decide which items need to be analyzed. Xfmea/RCM++ offers a choice of two configurable methods for this analysis: questions or ratings.

In this chapter

- ✓ System hierarchy
- ✓ Risk discovery

This chapter shows how to define the system configuration, and demonstrates how to perform preliminary risk assessments using a series of yes/no questions designed to determine whether further analysis may be beneficial.

4.1 System Hierarchy

Since the "Concept Phase" gates in your project plan have already been completed (see Chapter 3), the next gate is "Preliminary Risk Assessment."

Objectives

- Create the system hierarchy that shows the chandelier's assemblies and components.
- Perform a preliminary risk assessment to determine which assemblies/components require analysis by the FMEA team.

Note: If you want to perform the analysis steps on your own, you can continue working with the project you created in Chapter 3. If you prefer to examine a completed analysis, you can open the "Chandelier2 - Risk Discovery" project in the quick start database.

Solution

The chandelier is made up of the following assemblies and components:

- Frame
- Wiring
- Bulb and Socket
    - Bulb
    - Socket

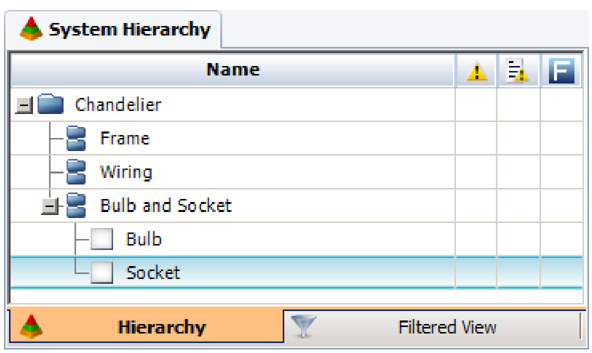
To add the first assembly under the chandelier item that you defined when you created the project, you select the chandelier and choose **System Hierarchy > Add Items > Add Next Level Item** then type the appropriate label into the **Name** field on the Properties tab in the Analysis panel.

You repeat the process to add the "Wiring" and "Bulb and Socket" assemblies. (Remember that when you're using the "Add Next Level" command you must have the parent item selected — in this case, the chandelier.)

To add each of the third-level components, you click the "Bulb and Socket" item and choose **System Hierarchy > Add Items > Add Next Level Item** then type the appropriate label into the **Name** field.

> **Tip:** If you happen to add an item to the wrong level in the system configuration, you can promote or demote it to the right location. For example, if you accidentally add the "Bulb and Socket" assembly in the next level under "Wiring," right-click the item and choose **Move > Promote** from the shortcut menu.

The completed configuration will look like the figure shown next.

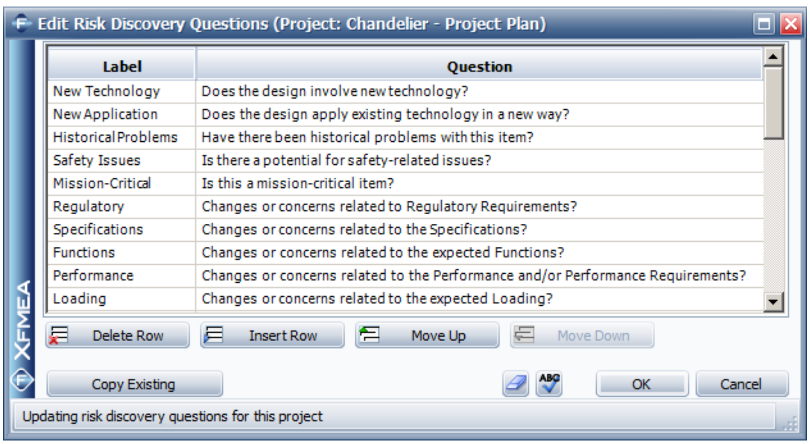


Risk Discovery Analysis

When the team meets to perform the preliminary risk assessments, you start by reviewing the criteria that will be used to evaluate each item. To see the risk discovery questions that have been defined for this project, you choose **Project > Management > Configurable Settings > RD Questions**.

Note: You can also open the Edit Risk Discovery Questions window from the Project Properties window's Configurable Settings tab by clicking the **Edit** icon associated with the "Use Risk Discovery Questions" option.

The following picture shows the first 10 of the 30 questions that will be available for any risk discovery analysis performed in this project.



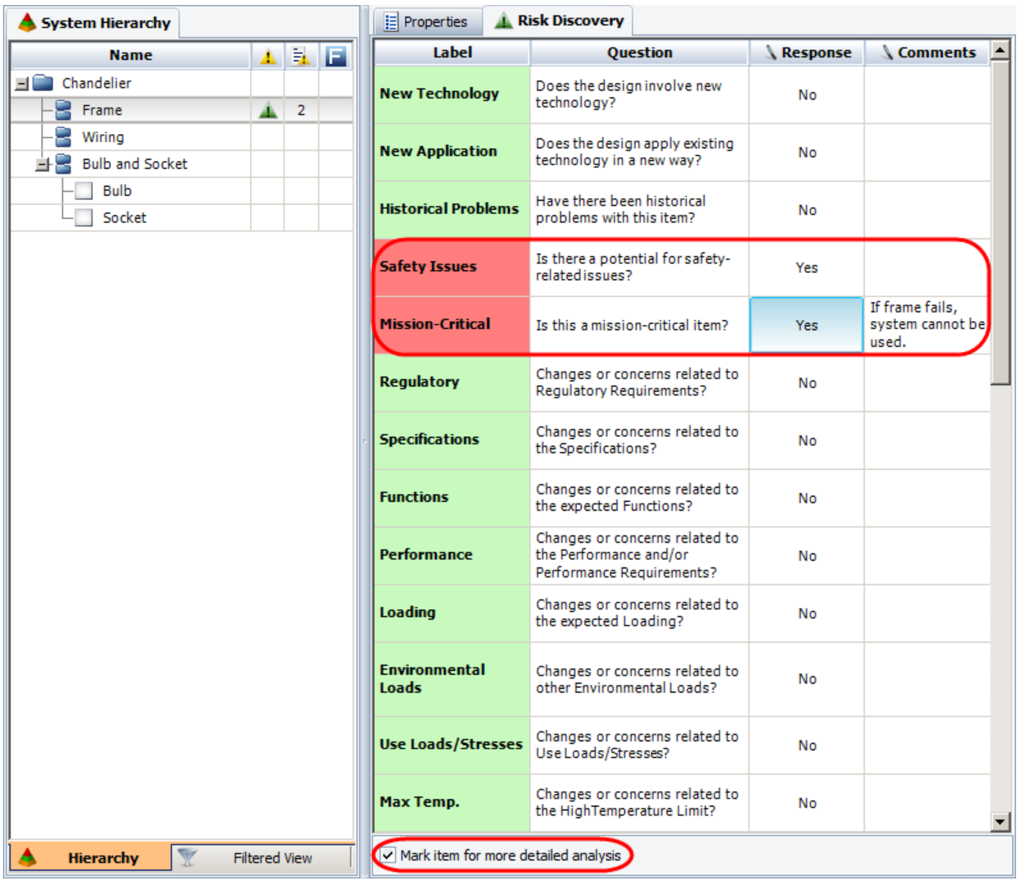
After the team agrees to use these questions without modification, you close the window, then proceed to analyze the first assembly ("Frame").

In the system hierarchy, you select the item and choose **Analyses > Planning > Add Risk Discovery**. The software adds a new **Risk Discovery** tab to the Analysis panel and puts the  icon into the Risk Discovery column of the system hierarchy.

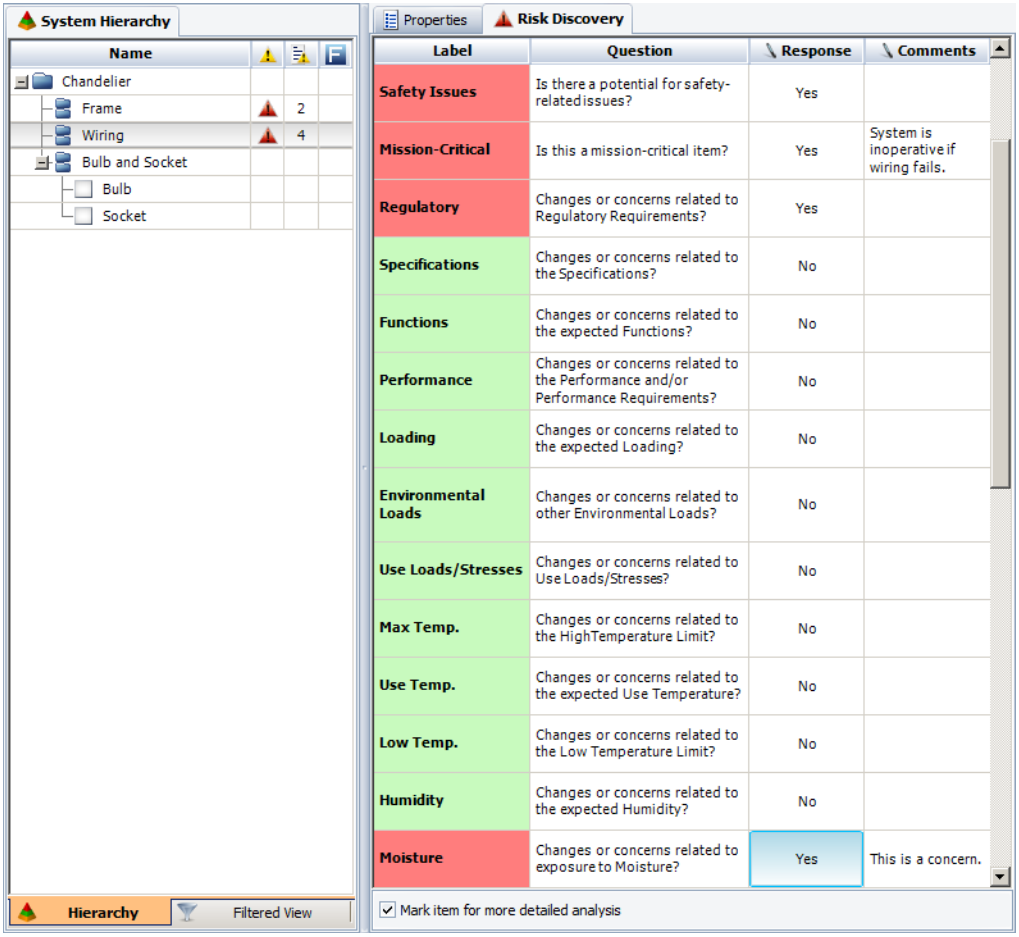
When they consider each of these issues for the frame, the team answers "yes" to two questions: the frame is mission-critical and there is a potential for safety-related issues if the frame breaks. To record this in the risk discovery worksheet, you click the **Response** cells of the **Safety Issues** and **Mission-Critical** rows to toggle the answers from "No" (green) to "Yes" (red.) For the mission-critical question, you also use the **Comments** field to enter the team's reason for answering "yes" to this question.

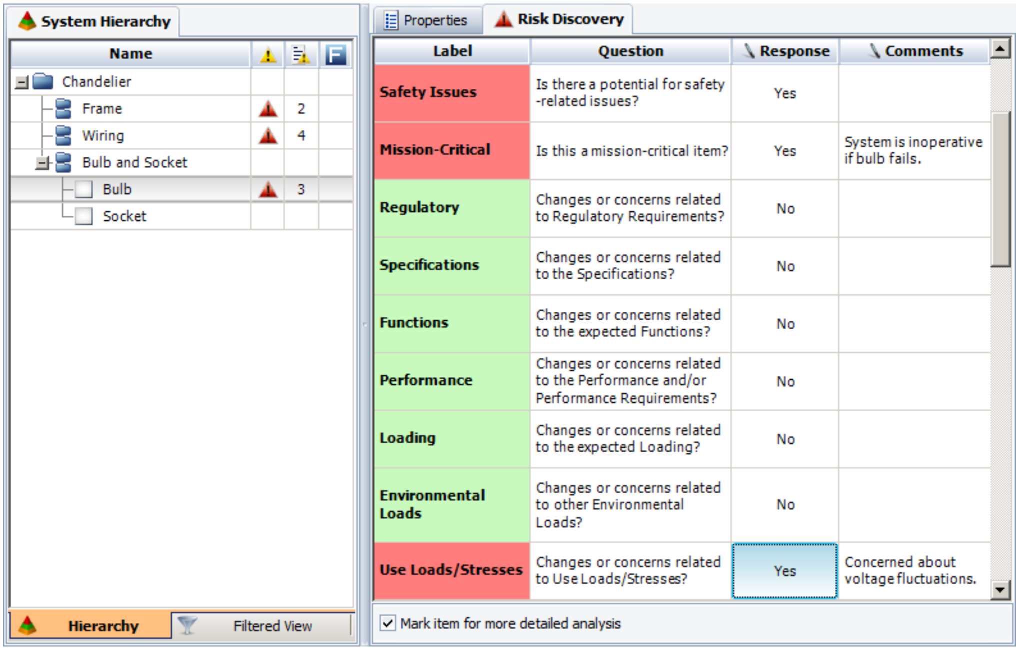
Based on these two concerns, the team agrees that the item does warrant further analysis via an FMEA, so you leave the **Mark item for more detailed analysis** check box selected.

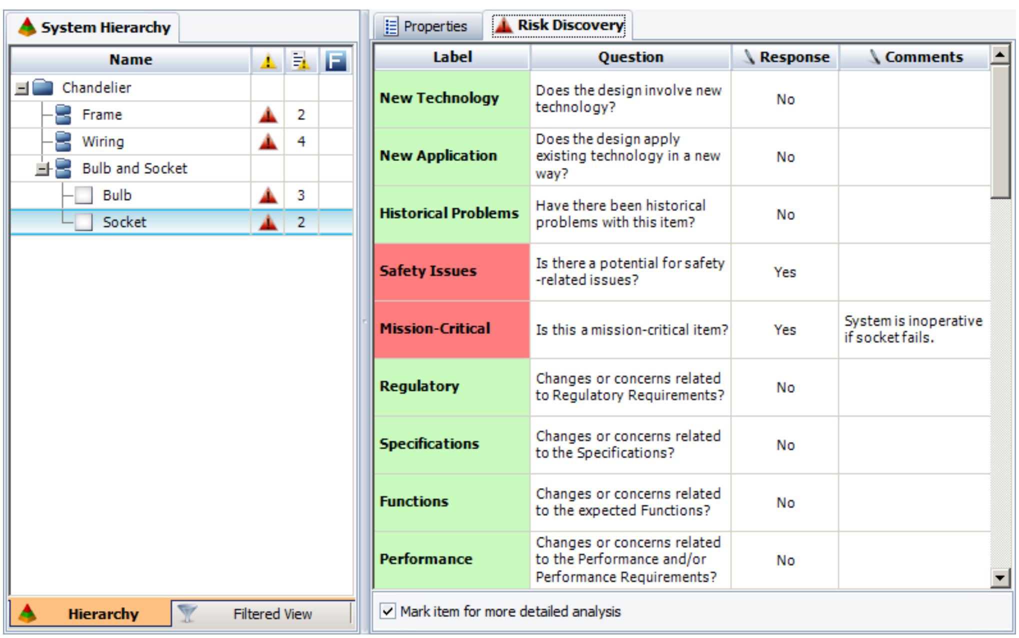
The completed analysis for the frame looks like the figure shown next:



You also record the analyses performed for the wiring, bulb and socket, as shown in the following pictures. Note that these items are also marked for more detailed analysis.




System Hierarchy
Name
Chandelier
Frame 2
Wiring 4
Bulb and Socket
Bulb 3
Socket
Hierarchy
Filtered View
Properties
Risk Discovery
Label
Question
Response
Comments
Safety Issues
Is there a potential for safety -related issues?
Yes
Mission-Critical
Is this a mission-critical item?
Yes
System is inoperative if bulb fails.
Regulatory
Changes or concerns related to Regulatory Requirements?
No
Specifications
Changes or concerns related to the Specifications?
No
Functions
Changes or concerns related to the expected Functions?
No
Performance
Changes or concerns related to the Performance and/or Performance Requirements?
No
Loading
Changes or concerns related to the expected Loading?
No
Environmental Loads
Changes or concerns related to other Environmental Loads?
No
Use Loads/Stresses
Changes or concerns related to Use Loads/Stresses?
Yes
Concerned about voltage fluctuations.
Mark item for more detailed analysis


System Hierarchy
Name
Chandelier
Frame 2
Wiring 4
Bulb and Socket
Bulb 3
Socket 2
Hierarchy
Filtered View
Properties
Risk Discovery
Label
Question
Response
Comments
New Technology
Does the design involve new technology?
No
New Application
Does the design apply existing technology in a new way?
No
Historical Problems
Have there been historical problems with this item?
No
Safety Issues
Is there a potential for safety -related issues?
Yes
Mission-Critical
Is this a mission-critical item?
Yes
System is inoperative if socket fails.
Regulatory
Changes or concerns related to Regulatory Requirements?
No
Specifications
Changes or concerns related to the Specifications?
No
Functions
Changes or concerns related to the expected Functions?
No
Performance
Changes or concerns related to the Performance and/or Performance Requirements?
No
Mark item for more detailed analysis

Updating the Project Plan

Now that you are finished with all the preliminary risk assessments, you choose **Project > Management > Project Planner** so you can update the project plan. You double-click the **Preliminary Risk Assessment** gate, then enter the actual start date of **3/29/2022** and the actual completion date of **4/4/2022**. After the update, the plan appears as shown next.

Name	Status	Planned Start Date	Planned Completion Date	Actual Completion Date
Project Plan Template		3/1/2022	7/13/2022	
Concept Phase		3/1/2022	3/28/2022	3/21/2022
Requirements & Goals		3/1/2022	3/14/2022	3/10/2022
Environment & Usage		3/15/2022	3/28/2022	3/21/2022
Design Phase		3/29/2022	5/23/2022	
Preliminary Risk Assessment		3/29/2022	4/4/2022	4/4/2022
DFMEA		4/5/2022	4/25/2022	
Compute Baseline Reliability		4/26/2022	5/2/2022	
Reliability Importance Analysis		5/3/2022	5/9/2022	
Reliability Allocation		5/10/2022	5/16/2022	
Update DFMEA		5/17/2022	5/23/2022	

Performing Design FMEAs 5

FMEA and FMECA are methodologies designed to identify failure modes for a product or process, to assess the risk associated with those failure modes, to rank the issues in terms of importance and to identify and carry out corrective actions that address the most serious concerns. Typically, a *design FMEA* (DFMEA) focuses on concerns about the design itself while a *process FMEA* (PFMEA) focuses on issues that may be caused during the manufacturing process.

This chapter demonstrates the process for performing DFMEAs and recording the analysis data in the software. The basic analysis process would be very similar for PFMEAs, although the underlying analysis assumptions, RPN rating scales, etc. would be different.

In this chapter

- ✓ FMEA creation
- ✓ FMEA structure
- ✓ Risk priority numbers
- ✓ Plots
- ✓ Actions
- ✓ Reports

5.1 Failure Modes and Effects Analysis (FMEA)

After you have defined the system configuration and performed the preliminary risk assessment (see Chapter 4), the next gate in the project plan is to perform DFMEAs for the items that require further analysis.

Objectives

- Identify and record the functions, failures, effects, causes and controls for each assembly/ component in the chandelier.
- Calculate the risk priority numbers (RPNs), then use them to understand the risk in the design and prioritize issues for corrective action.
- Create graphical charts based on the FMEA data.

- Identify and record the recommended actions that will be performed to reduce the risk in the design.
- Create print-ready reports for the completed FMEAs.

> **Note:** If you want to perform the analysis steps on your own, you can continue working with the project you used in earlier chapters. This guide provides instructions for recording one branch of one FMEA. If you prefer to examine a completed analysis, you can open the “Chandelier3 - DFMEAs” project in the quick start database.

Solution

When the team is ready to perform the DFMEA for the socket, you select the item in the system hierarchy and then choose **Analyses > FMEA > Add FMEA**. The software adds a new **FMEA** tab to the Analysis panel and puts the  icon into the FMEA column of the system hierarchy.

The Add Function window displays automatically when you create a new FMEA. You type the following description into the **Function** field:

```
Provide electricity to bulb
```

You leave the **Name** field as an asterisk so that it can be populated automatically by the software when you save the record. (This field has a maximum of 50 characters and is used in situations in which the full description would be too long to display.)

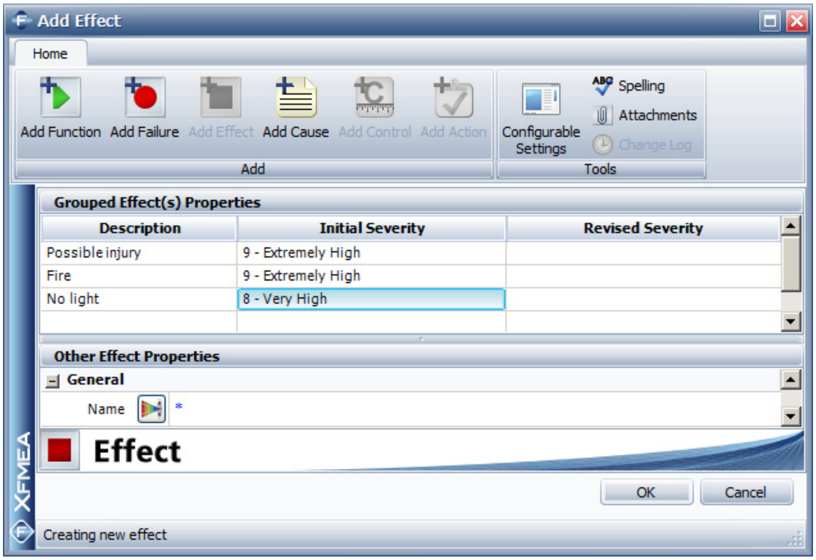
When you click the **Add Failure** button at the top of the window, the software saves the new function record and opens the Add Failure window. You type the following description into the **Failure** field:

```
Short circuit occurs
```

You then click the **Add Effect** button to open the Add Effect window.

For this project, the FMEA structure is set to **Grouped Effects and Causes** (see page 11 in Chapter 3), which means that the Add Effect window allows you to enter severities for more than one effect in the same data entry window. The effect descriptions will be saved separately in the database, but they will be displayed together in the analysis views and report output. The software will automatically use the highest severity rating that has been defined for any of the possible effects.

For this failure mode, you type three possible effects and assign a different initial severity rating for each one. To assign each rating, you double-click inside the **Initial Severity** column and choose the rating from the drop-down list. When you are finished, the Add Effect window looks like the one shown next.



You click the **Add Cause** button and then type the following description into the **Cause** field:

```
Corrosion inside the socket
```

The team will assign the initial occurrence and initial detection ratings after they have identified all of the prevention and detection controls that might affect those ratings. So you click the **Add Control** button to open the Add Control window.

Controls: A control is a method or action that is planned or currently in place to reduce or eliminate the risk associated with a particular failure cause. While the control types are configurable in the software, practitioners usually classify the controls as "Prevention" or "Detection," where:

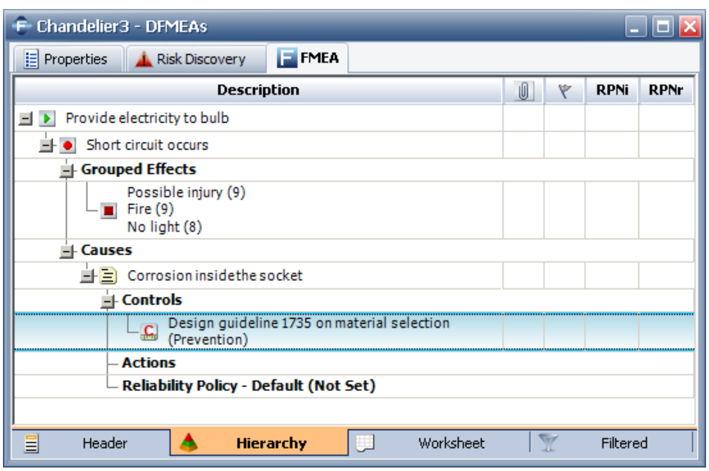
- Prevention controls are intended to reduce the likelihood that the problem will occur.
- Detection controls are intended to increase the likelihood that the problem will be detected before it reaches the end user.

Analysts will typically consider all of the prevention controls when assigning the initial occurrence rating to a cause and they will consider all of the detection controls when setting the initial detection rating.

You type the following description into the **Control** field:

```
Design guideline 1735 on material selection
```

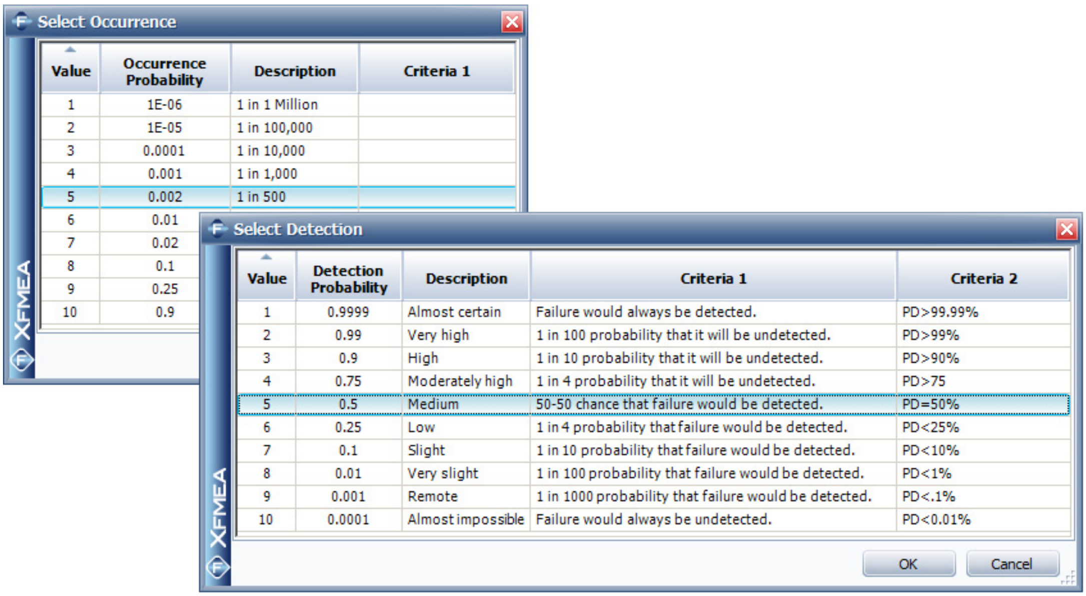
Then you choose **Prevention** from the **Control Type** drop-down list and click **OK** to save the record and close the window. The FMEA hierarchy looks like the picture shown next.



Now that the controls have been defined, the next step is to go back to the cause record and record the team's occurrence and detection ratings. You double-click the "Corrosion inside the socket" cause to edit the record properties.

You click inside the **Initial Occurrence** field and then click the **Select Existing** icon in the field to see the occurrence rating scale that has been assigned for this project. You choose **5 (1 in 500)** and click **OK** to close the Select Occurrence window.

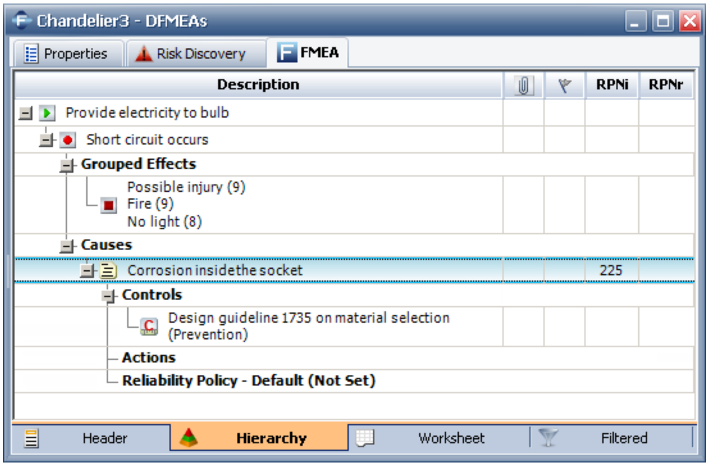
You do the same for the **Initial Detection** field and choose **5 - Medium**. The following picture shows both the occurrence and detection scales defined for this project.



Value	Occurrence Probability	Description	Criteria 1
1	1E-06	1 in 1 Million	
2	1E-05	1 in 100,000	
3	0.0001	1 in 10,000	
4	0.001	1 in 1,000	
5	0.002	1 in 500	
6	0.01		
7	0.02		
8	0.1		
9	0.25		
10	0.9		

Value	Detection Probability	Description	Criteria 1	Criteria 2
1	0.9999	Almost certain	Failure would always be detected.	PD>99.99%
2	0.99	Very high	1 in 100 probability that it will be undetected.	PD>99%
3	0.9	High	1 in 10 probability that it will be undetected.	PD>90%
4	0.75	Moderately high	1 in 4 probability that it will be undetected.	PD>75
5	0.5	Medium	50-50 chance that failure would be detected.	PD=50%
6	0.25	Low	1 in 4 probability that failure would be detected.	PD<25%
7	0.1	Slight	1 in 10 probability that failure would be detected.	PD<10%
8	0.01	Very slight	1 in 100 probability that failure would be detected.	PD<1%
9	0.001	Remote	1 in 1000 probability that failure would be detected.	PD<.1%
10	0.0001	Almost impossible	Failure would always be undetected.	PD<0.01%

You click **OK** to save the changes in the cause record and return to the FMEA hierarchy. The calculated initial RPN is displayed in the hierarchy, as shown next.



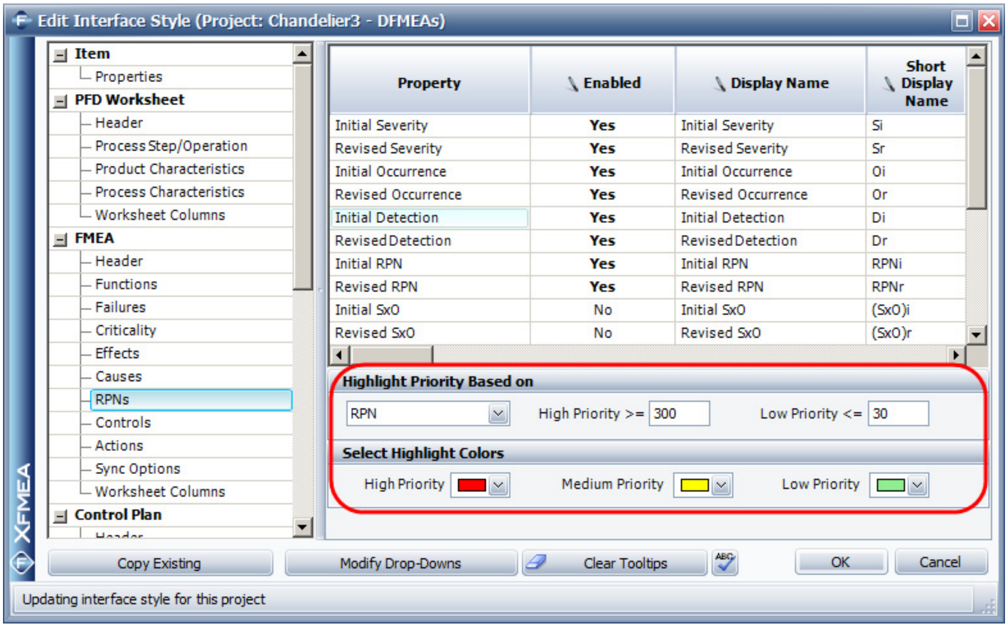
Then you continue recording the rest of the socket FMEA in a similar manner.

Evaluating the RPNs

Remember that while the quick start guide describes the steps for only one branch of one FMEA, the "Chandelier3 - DFMEAs" project contains the completed FMEAs for all four assemblies/components. For the rest of this chapter, you will need to work with the entire data set available in the sample project.

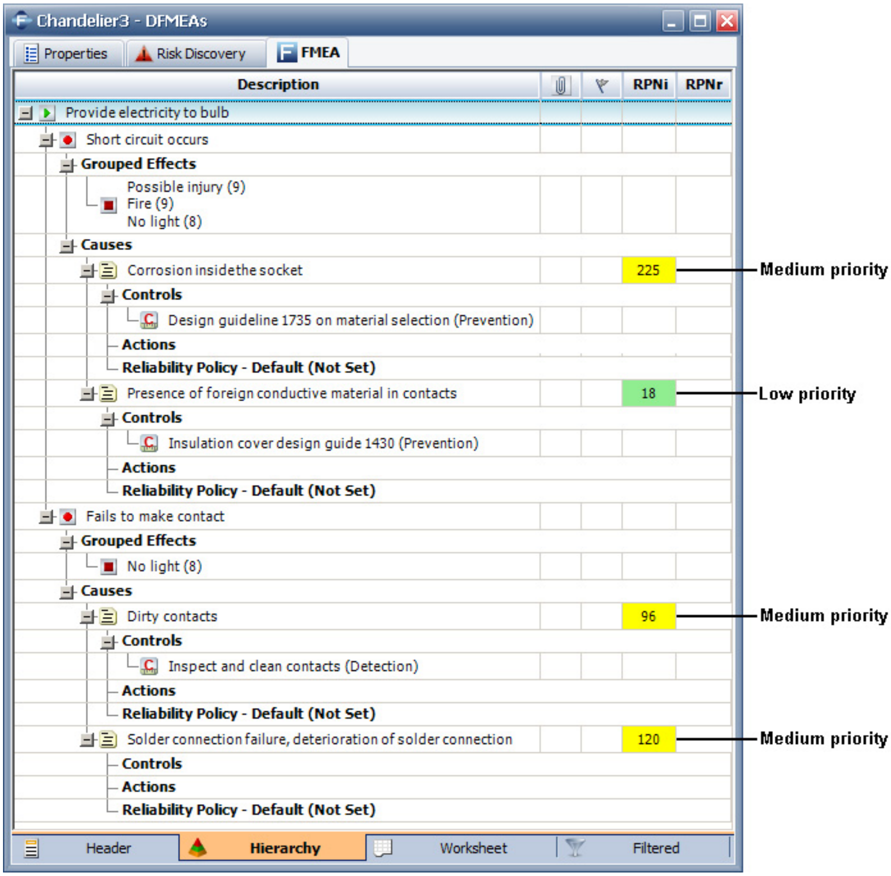
Once the FMEA team has identified the functions, failure modes, effects, causes, controls and initial RPNs for all four of the chandelier assemblies/components, you begin to use the calculated RPNs as a way to evaluate the risk in the design and to prioritize the issues for corrective action.

You will use the Priority Highlights feature to scan through the FMEAs to see which issues meet the high, medium and low priority thresholds. To show the team what thresholds have been established in this project, you choose **Project > Management > Configurable Settings > Interface Style** to open the Edit Interface Style window then use the navigation panel to display the FMEA > RPNs page. As shown below, when the highlight colors are turned on for the analyses in this project, the issue will be colored green if the RPN is less than or equal to 30, yellow if the RPN is 31 to 299 and red if the RPN is 300 or higher.



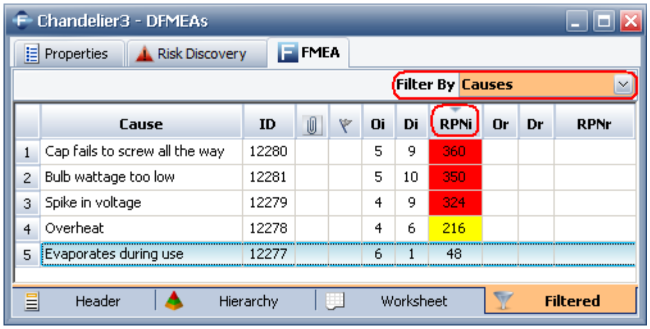
You close the interface style window and return to the socket FMEA. Then you choose **FMEA > Tools > Highlight Priority** to turn on the priority highlights.

You see that one issue is highlighted in green to indicate low priority and the rest are highlighted in yellow to indicate medium priority. (In the following picture, labels have been added to identify each highlight color.)

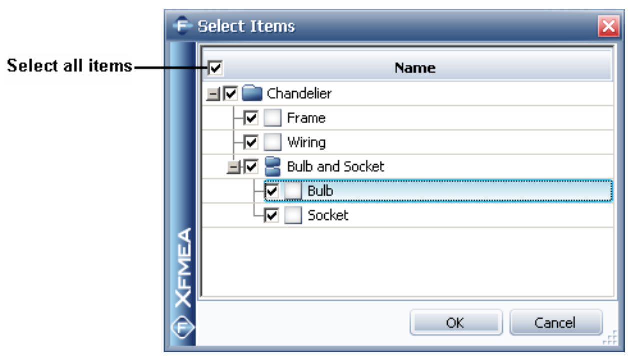


The team reviews the highlights for the other FMEAs in a similar manner.

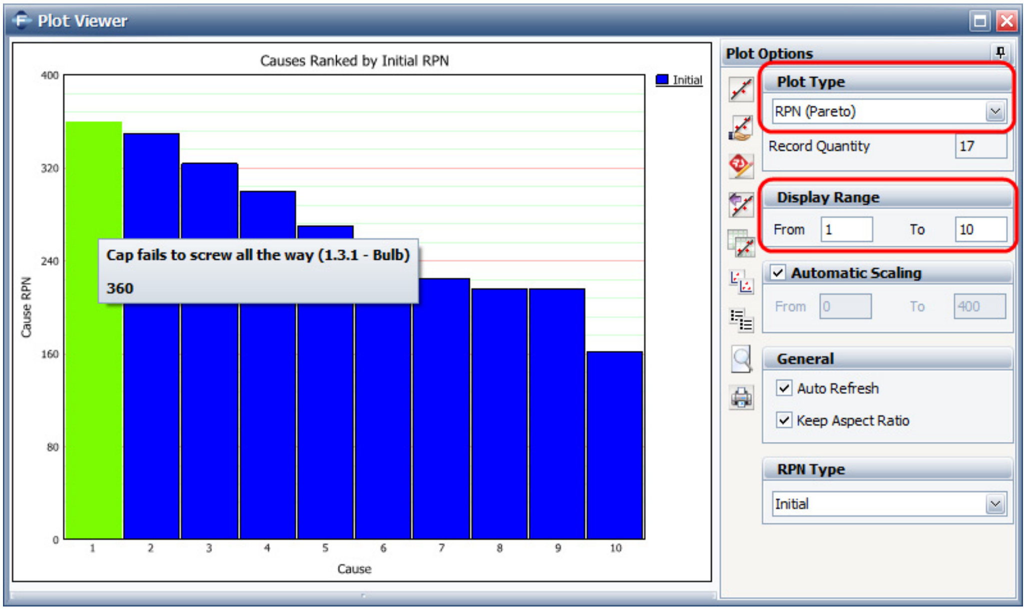
To look at the RPNs in a second way, you will use the Filtered view to see lists of all the causes in each FMEA sorted by RPN. First you review the FMEA for the bulb and click the **Filtered** tab at the bottom of the panel. Then you choose **Causes** from the **Filter By** drop-down list in the upper-right corner. To sort the list by initial RPN, you click inside the header for the **RPNi** column. The following picture shows the sorted list for the bulb FMEA. You review the rest of the FMEAs in a similar manner.



For a third perspective, you choose **Home > Reporting > Plots** to generate some graphical charts based on the analysis data. When prompted to specify which data will be reflected in the charts, you click the check box in the column header to select all items, as shown next, and then click **OK**.

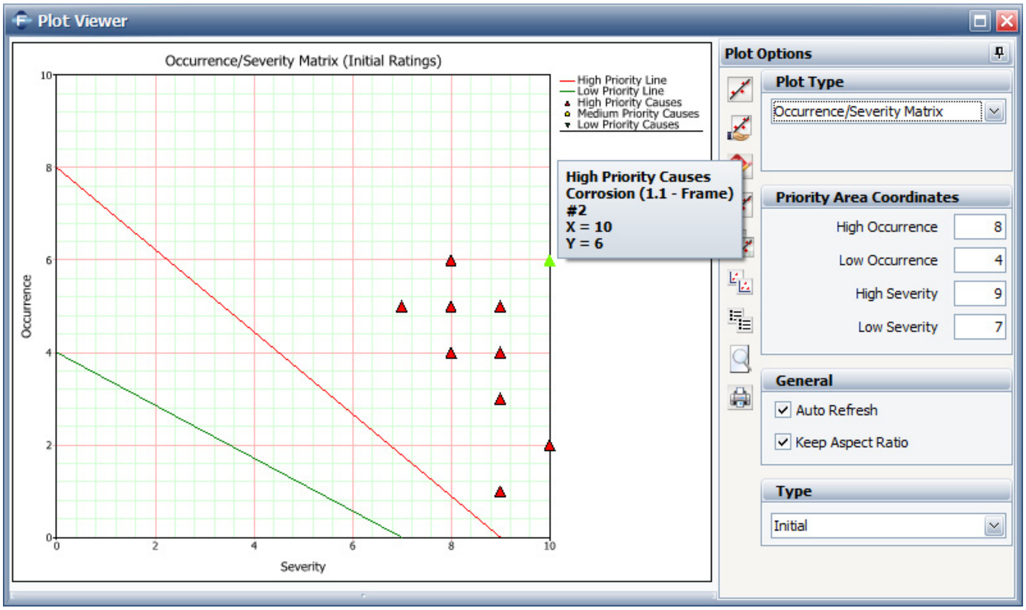


In the Plot Viewer window, you choose **RPN (Pareto)** in the **Plot Type** field. In the **Display Range** area, you enter **1** to **10** in the **From** and **To** fields to display the top ten issues ranked by RPN. As shown next, when you point to a bar in the chart, the software displays the cause description, the item that the FMEA belongs to (in parentheses) and the RPN. (*Plot settings have been adjusted for optimum printing, but content remains unchanged*.)



Tip: The **Plot Type** field allows you to select which chart will be displayed. When a bar chart is selected, the **Display Range** area allows you to specify the number of records to be displayed in the plot. For example, since there are 17 cause records in the chandelier FMEAs, you could specify to view records 1 through 5, 1 through 10, 1 through 17, etc.

Next, you change the plot type to **Occurrence/Severity Matrix**, which displays the severity ratings (S) on the horizontal axis and occurrence ratings (O) on the vertical axis, then plots each cause at the intersection of its severity and occurrence ratings. You can see that when the analysis considers only the S and O components of the RPN equation, all of the issues fall into the “High Priority” range. Once again, pointing to a data point in the matrix displays the name of the failure cause and other relevant details, as shown in the following picture. (*Plot settings have been adjusted for optimum printing, but content remains unchanged*.)



When you are finished reviewing the plots, you close the Plot Viewer window.

Managing Recommended Actions

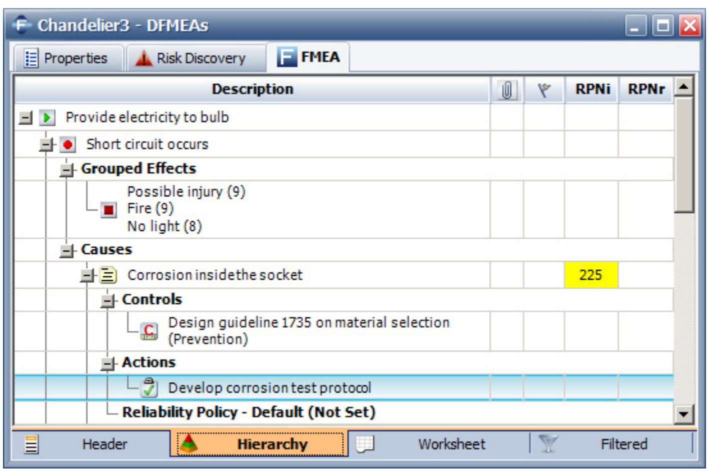
The next step is to identify, assign and track the completion of the recommended actions that will help to reduce the risk associated with potential failures.

The FMEA team identifies the actions that need to be performed to improve the chandelier design, and you record the details in the appropriate locations within each FMEA. (*Note that the actions have already been created in the sample data*.)

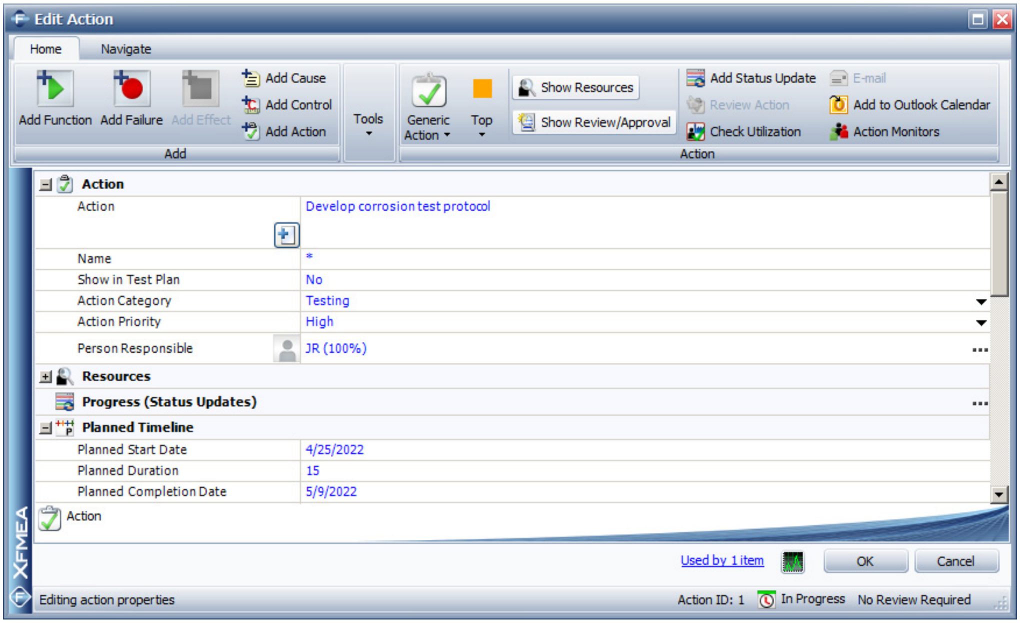
Actions Management in Xfmea/RCM++: One of the most costly mistakes among FMEA practitioners is the failure to follow up and track the completion of recommended actions. Xfmea/RCM++ provides multiple features to help your organization implement the improvements that are identified during the FMEA activity. For example:

- You can assign an action to any user with an account in the database and that action will display in the user's personalized Synthesis portal.
- You can configure the database to send alerts via e-mail, SMS text message or Synthesis portal message.
- You can generate reports for action tracking, such as a list of actions sorted by due date or action category.
- You can use the same action resource in more than one place within a given FMEA, or in different FMEAs within the same project.

For example, to view the action that was assigned to the socket FMEA, you select the **Socket** item in the system hierarchy and then click the **FMEA** tab in the Analysis panel. The first branch of the FMEA hierarchy looks like the picture shown next.



You double-click the action record ("Develop corrosion test protocol") to view its properties, as shown next.



You close the properties window and then review the rest of the FMEAs in a similar manner.

Generating a Report

When you are ready to generate a print-ready report for the analysis, you select the chandelier item, then choose **Home > Reporting > Reports**. The Reports window provides a choice of predefined and custom report forms that can be included in a report document generated in either Microsoft Word® or Excel.

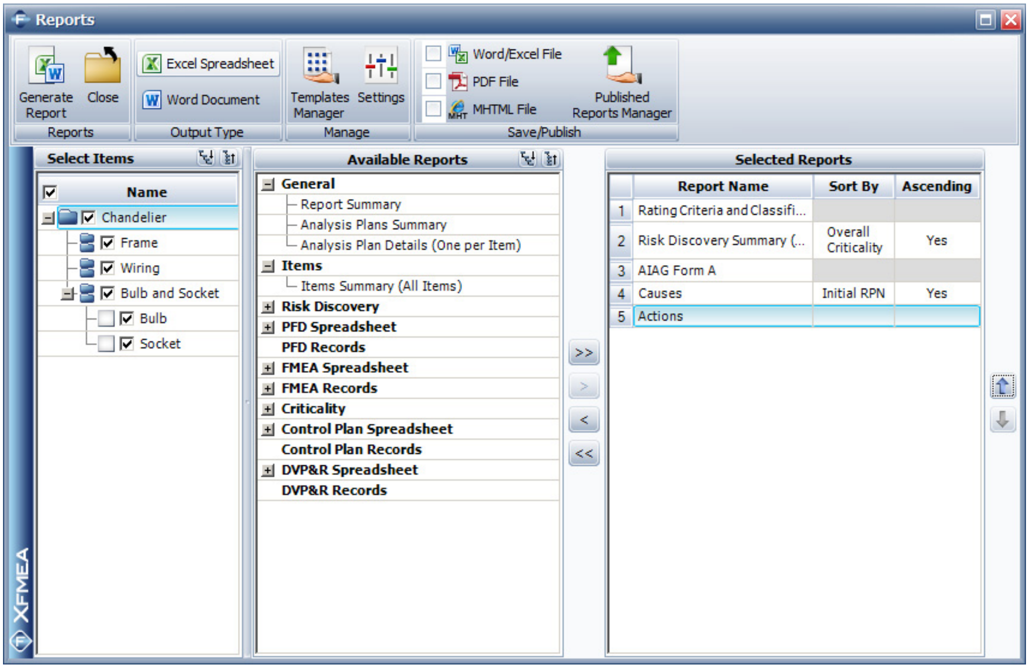
You first remove any existing reports in the **Selected Reports** area by clicking the **Exclude All** button (<<).

To build the desired report, you double-click, (or drag and drop) the following report forms to move them into the **Selected Reports** area.

- Rating Criteria and Classification
- Risk Discovery Summary (with Questions)
- AIAG Form A

- Causes
- Actions

For the Risk Discovery Summary (with Questions) and Actions reports, you click inside the **Sort By** column for each report to specify the sort order, as shown next.



You select the **Excel Spreadsheet** option, then click **Generate Report** and specify the name and location where the report file will be saved.

The report will then open automatically in Microsoft Excel. When you are finished reviewing the reports, you close Excel and the Reports window.

Updating the Project Plan

After you are finished creating all the design FMEAs and performing all the tasks associated with that, you choose **Project > Management > Project Planner** so you can update the project plan. You then double-click the **DFMEA** gate, then enter the actual start date of **4/5/2022** and the actual completion date of **4/25/2022**. After the update, the plan appears as shown next.

Name	Status	Planned Start Date	Planned Completion Date	Actual Completion Date
Chandelier3 - DFMEAs		3/1/2022	7/13/2022	
Concept Phase		3/1/2022	3/28/2022	3/21/2022
Requirements & Goals		3/1/2022	3/14/2022	3/10/2022
Environment & Usage		3/15/2022	3/28/2022	3/21/2022
Design Phase		3/29/2022	5/23/2022	
Preliminary Risk Assessment		3/29/2022	4/4/2022	4/4/2022
DFMEA		4/5/2022	4/25/2022	4/25/2022
Compute Baseline Reliability		4/26/2022	5/2/2022	
Reliability Importance Analysis		5/3/2022	5/9/2022	
Reliability Allocation		5/10/2022	5/16/2022	
Update DFMEA		5/17/2022	5/23/2022	

FMRA - Reliability Estimation

6

The innovative failure modes and reliability analysis (FMRA) tool in Xfmea/RCM++ enables you to use the information from the system hierarchy and FMEAs to perform a variety of reliability-related analyses. One application for this tool is to generate a preliminary *quantitative* estimate of the system's baseline reliability using the *qualitative* occurrence ratings specified in the project's FMEAs.

In this chapter

- ✓ Failure modes and reliability analysis (FMRA)
- ✓ Estimating the system reliability
- ✓ Restore points
- ✓ FMRA vetting

Specifically, you can use the occurrence ratings to assign quantitative models to describe the probability of failure due to each failure cause identified in the FMEA, and then you can estimate the system's reliability based on those models. As better information about the system becomes available, you can then update the FMRA to improve your understanding of the system's reliability and the components/failure modes that have the biggest impact on that reliability.

6.1 Using the FMRA to Generate a Baseline Reliability Estimate

After completing the assembly- and component-level FMEAs (see Chapter 5), the next step in the project plan is to generate a baseline reliability estimate for the chandelier. Since little data is available at this point in the process, you will start by using the occurrence ratings assigned in the FMEAs.

Objectives

- View the FMRA interface and customize it so you only see the columns that are relevant for estimating the system's reliability.
- Produce a first draft of the FMRA and use it to generate a preliminary estimate of the system's baseline reliability.

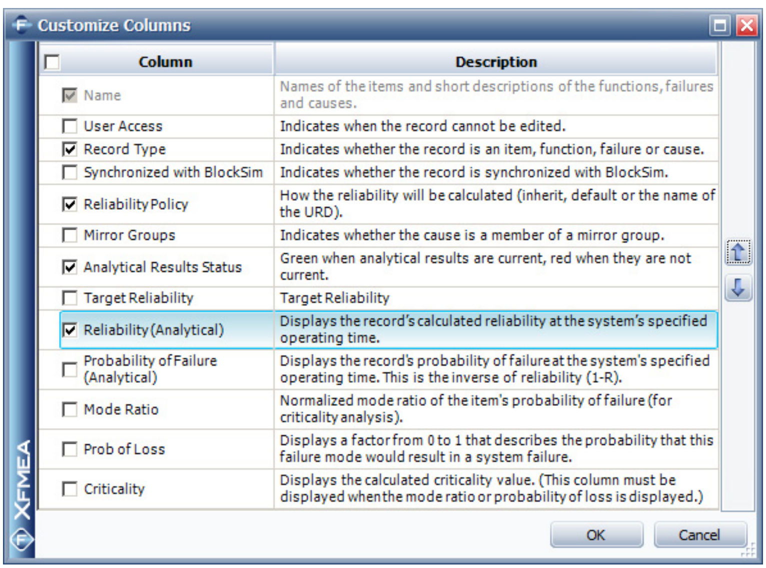
- Create a restore point of the entire project to use as a "baseline" before you begin adjusting the analysis.
- Begin the "FMRA vetting" process by reviewing and updating the first draft.

Note: If you want to perform the analysis steps on your own, you will need to start from the "Chandelier3 – DFMEAs" project in the quick start database, which contains the full FMEAs for all four assemblies/components. If you prefer to examine a completed analysis, please use "Chandelier4 - FMRA Draft" for the first part of the example and "Chandelier5 - FMRA Revised" for the second part.

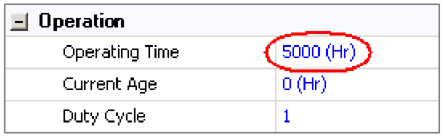
Solution

After opening the project in Xfmea/RCM++, you click the **FMRA** tab in the System panel. This hierarchy panel displays the system hierarchy along with all the functions, failures and causes that are defined in the FMEAs. (If this tab is not already visible on your computer, choose **View > Show > Show FMRA**.)

To select which columns to show on your computer, you right-click a column header in the FMRA and choose **Customize Columns**. You only want to see the columns that are relevant to estimating the system's reliability (and the reliabilities of its components), so you make the selections shown next. (*Note that you must perform this step even if you are simply examining a completed analysis. These settings are not stored in the database or project. After you complete the examples in this guide, you can return to this window to configure the workspace to fit your particular preferences*.)

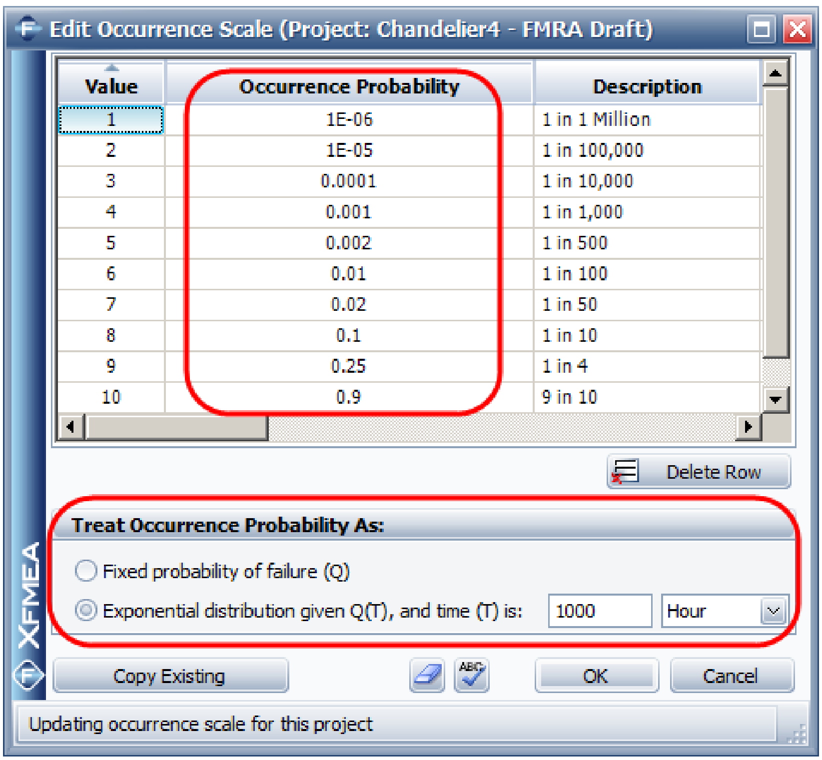


You close the window and return to the FMRA hierarchy. Then you click the chandelier (i.e., the top-level item) and enter **5000** for the **Operating Time** on the Properties tab. The analysis will estimate the reliability at 5,000 hours.



Next, you choose **Project > Management > Configurable Settings > Occurrence** to see the occurrence scale that is in effect for this project and confirm that the settings will allow the software to create appropriate probability of failure models for use in the FMRA.

The probability of failure model that is associated with each rating in the scale will be determined by the number in the **Occurrence Probability** column and the option selected in the **Treat Occurrence Probability As** area.



In this case, you know that the FMEA team assigned occurrence ratings based on the probability that the failure would occur by 1,000 hours of operation, so it is possible to use a time-dependent exponential distribution instead of a fixed probability. This will allow the software to calculate the probability of failure for any operating time specified for the analysis (which is 5,000 hours in this case).

You make sure the **Exponential distribution** option is selected and you set *T* to 1,000 hours. With this setting, an exponential model will be built for each rating using the probability of failure entered in the **Occurrence Probability** field and the time specified for *T*.

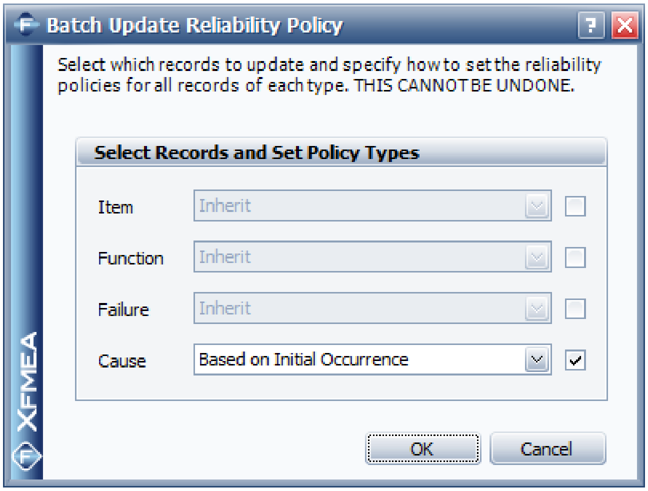
Probability Models in the FMRA: If you choose to associate exponential models with the occurrence ratings, the parameter for each model will be estimated using the same calculation performed in the Quick Parameter Estimator. The probability of failure (Q) and time (T) that you specified in the scale are used to solve for the lambda parameter of the exponential distribution as follows:

$$1 - Q(T) = R(T) = e^{-\lambda t}$$

$$\frac{-\ln(1 - Q(T))}{t} = \lambda$$

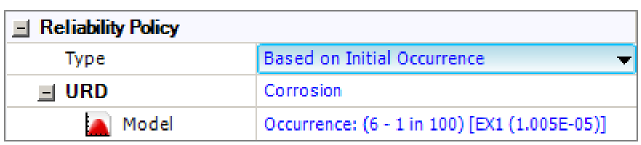
After confirming that the occurrence probability values reflect the criteria that the team used for the FMEAs, you close the window and return to the system hierarchy.

The next step is to configure the software so each cause is automatically assigned an appropriate model based on the initial occurrence ratings from the FMEAs. While you could do this by modifying the reliability policy for each cause individually (on the Properties tab), you know it will be faster to update all the causes simultaneously by choosing **FMRA > Calculations > Policy Update**. In the window that appears, you select **Cause** and choose **Based on Initial Occurrence** from the drop-down list.



After you click **OK**, the reliability policy type for each cause record is changed to **Based on Initial Occurrence**. Now, when you click any cause record, you can see the updated policy and the assigned model on the Properties tab.

For example, for the "Corrosion" cause shown next, the name of the model indicates that it is based on an **Occurrence** rating of **6**, which in this project corresponds to a probability of **1 in 100** at 1,000 hours. The information in brackets indicates that the model uses a 1-parameter exponential distribution (**EX1**), and the value of lambda is **1.005E-05**.



You can see that the application has also created a *universal reliability definition* (*URD*) for the failure mode. A URD is a Synthesis resource that compiles all of the relevant reliability and maintainability characteristics for a particular failure mode, component or assembly.

You scan through the FMRA to make sure that all of the models were assigned properly and then choose **FMRA > Calculations > Calculate (Reliability)** to solve for the system's baseline reliability. To color-code the reliability values (which uses a gradient from green to red to indicate highest to lowest values), you choose **FMRA > Calculations > Highlight**.

Note: By default, the software assumes that the occurrence of any one cause is sufficient for the entire system to fail (i.e., it assumes a reliability-wise series configuration). If you also have ReliaSoft's BlockSim software, you can synchronize the FMRA in Xfmea/RCM++ with RBDs or fault trees in BlockSim. You can then use the RBDs/fault trees to define more complex reliability-wise configurations in your FMRA, if appropriate.

The following picture shows a portion of the FMRA for this analysis. You can click the +/- buttons to expand/collapse different nodes in the hierarchy.

Name	Record Type	Reliability Policy	Reliability (Analytical)
Chandelier	Item	Inherit	0.849499
Frame	Item	Inherit	0.950943
Wiring	Item	Inherit	0.992525
Bulb and Socket	Item	Inherit	0.900051
Bulb	Item	Inherit	0.922861
Provide light	Function	Inherit	0.922861
Filament burns	Failure	Inherit	0.950990
Filament burns	Cause	Filament burns	0.950990
Bulb shatters	Failure	Inherit	0.990045
Overheat	Cause	Overheat	0.995010
Spike in voltage	Cause	Spike in voltage	0.995010
Base fails to make contact	Failure	Inherit	0.990040
Cap fails to screw all the way	Cause	Cap fails to screw all the way	0.990040
Insufficient Light	Failure	Inherit	0.990040
Bulb wattage too low	Cause	Bulb wattage too low	0.990040
Socket	Item	Inherit	0.975283
Provide electricity to bulb	Function	Inherit	0.975283
Short circuit occurs	Failure	Inherit	0.990035
Corrosion inside the socket	Cause	Corrosion inside the socket	0.990040
Presence of foreign conductive material in contact	Cause	Presence of foreign conductive material...	0.999995
Fails to make contact	Failure	Inherit	0.985100
Dirty contacts	Cause	Dirty contacts	0.995010
Solder connection failure/deterioration	Cause	Solder connection failure/deterioration	0.990040

The value shown in the **Reliability (Analytical)** column for the top-level item is the computed baseline reliability for the entire chandelier at 5,000 hours (84.95%). To calculate this value, the occurrence rating for each cause was converted into an exponential distribution. Then these distributions were used to obtain the reliability for each failure mode (i.e., the probability that none of the causes for that failure mode would occur). Finally, these reliabilities were "rolled up" to get the reliabilities of the components/ assemblies and then the system.

Note: In this example, since we are assuming a reliability-wise series configuration, "rolling up" from a lower level is done by simply multiplying the calculated reliability values at the lower level and assigning the result to the higher-level record that is set to "Inherit." For example, looking at the "Overheat" and "Spike in voltage" cause records, the reliability is the reciprocal of the cause's probability of occurrence (i.e., the probability that the cause will *not* occur before the specified operating time). So, according to the above FMRA, the probability of the bulb not overheating before 5,000 hours is estimated to be 99.50%, and the probability of a spike in voltage not occurring is also 99.50%. Thus, the probability of the bulb not shattering before 5,000 hours (i.e., the failure mode's reliability) is 99.50% x 99.50% = 99.00%. This is then multiplied by the reliabilities of the other failure modes under the "Provide light" function to obtain the reliability of the bulb.

When you generate this first draft of the FMRA, you are aware that the computed values may be far from the true reliabilities. The next step is to work through the "FMRA vetting" process by carefully reviewing and updating the analysis with the goal of improving its accuracy and thereby achieving a more accurate understanding of the system's baseline reliability.

FMRA Vetting: In general, the FMRA vetting process involves these two steps:

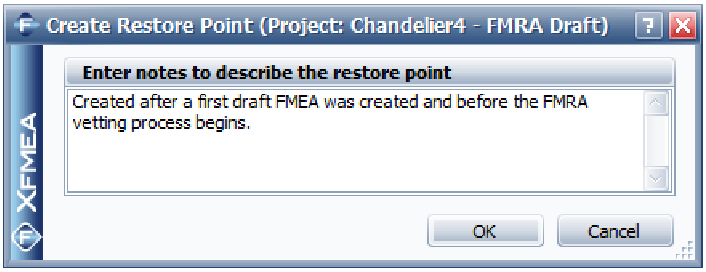
- **Cleaning Up**
  During this step, you review the failure causes that are being considered in the analysis and perform any cleanup that may be required to make sure the FMRA considers all the causes that impact the system's reliability, but does not consider causes that don't.
- **Reviewing and Validating Inputs**
  During this step, you examine the calculated reliability estimates for each record to see if they fit your expectations. If not, you determine which inputs to the FMRA and DFMEAs might need to be revised with better information.

The ReliaWiki resource portal provides more information about the FMRA vetting process at: http://www.ReliaWiki.org/index.php/Using_FMRA_to_Estimate_Baseline_Reliability.

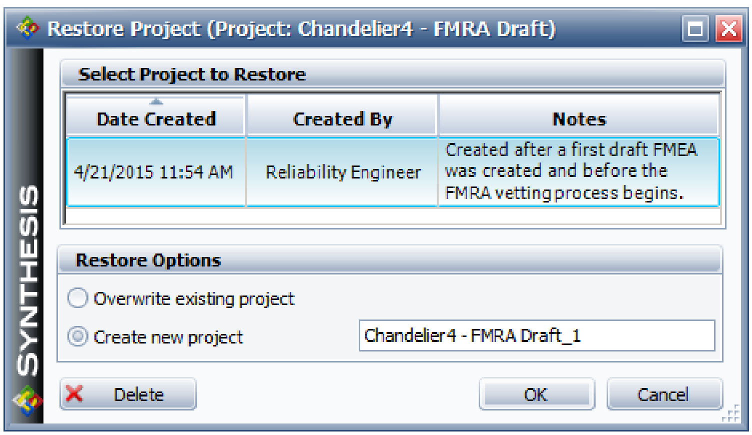
Creating a Restore Point

Before you begin the vetting process, you decide to create a *restore point* of the entire project that you can restore or roll back to at any point in the future.

To create the restore point, you choose **Project > Management > Restore Point > Create Restore Point** and enter text to indicate the purpose of the restore point, as shown next.



You click **OK** to create the restore point. Then you choose **Project > Management > Restore Point > Restore Project** and open the Restore Project window to confirm that the restore point was created.



If needed in the future, you will have the option to either roll back the existing project to the state it was in when this restore point was created (by choosing **Overwrite existing project**) or to restore the backup as a new project that is separate from the one you are currently working with (by choosing **Create new project**).

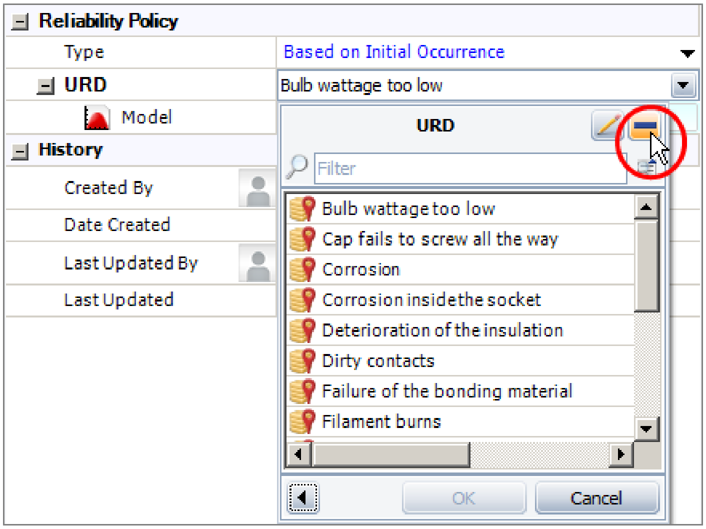
Reviewing and Updating the FMRA

The "Chandelier4 - FMRA Draft" project shows the completed analysis up to this point. If you wish to see the analysis after making the changes in the following sections, open the "Chandelier5 - FMRA Revised" project.

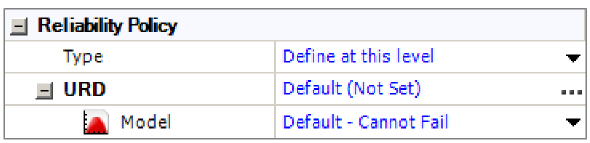
After saving a restore point of the project, you examine the FMRA and look for ways to improve it. One issue you notice is that the "Bulb wattage too low" failure cause (which occurs if the user installs the wrong type of bulb) was something that needed to be considered during the FMEA, but it should not affect the chandelier's calculated reliability.

Name	Record Type	Reliability Policy	Reliability (Analytical)
Chandelier	Item	Inherit	0.849499
Frame	Item	Inherit	0.950943
Wiring	Item	Inherit	0.992525
Bulb and Socket	Item	Inherit	0.900051
Bulb	Item	Inherit	0.922861
Provide light	Function	Inherit	0.922861
Filament burns	Failure	Inherit	0.950990
Filament burns	Cause	Filament burns	0.950990
Bulb shatters	Failure	Inherit	0.990045
Overheat	Cause	Overheat	0.995010
Spike in voltage	Cause	Spike in voltage	0.995010
Base fails to make contact	Failure	Inherit	0.990040
Cap fails to screw all the way	Cause	Cap fails to screw all the way	0.990040
Insufficient Light	Failure	Inherit	0.990040
Bulb wattage too low	Cause	Bulb wattage too low	0.990040
Socket	Item	Inherit	0.975283

To prevent the software from considering this cause, you select it in the FMRA. Then, on the Properties tab, you double-click inside the **URD** field and click the button to remove the assigned URD.

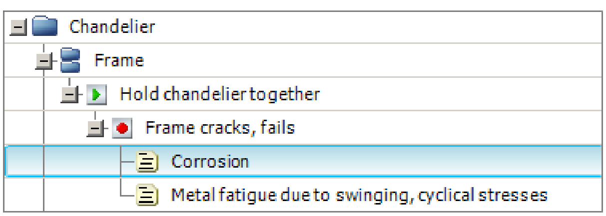


The software will assign a model with 100% reliability ("Default - Cannot Fail"), as shown next.

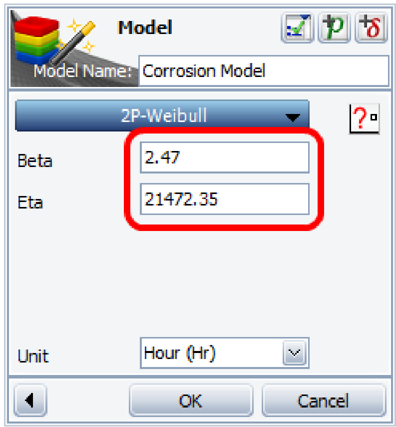


By assigning this default model, the cause record will essentially be ignored in the reliability calculations because the cause reliability will always be 100%.

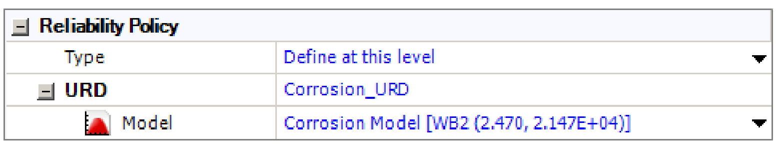
Next, you decide to replace the exponential distribution for the frame's "Corrosion" failure cause with a model that more accurately reflects the wearout behavior for this failure mechanism.



After researching this issue, you discover that another design team has analyzed data for the corrosion failure mode in a similar chandelier frame. The data set was fitted to a Weibull distribution with beta = 2.47 and eta = 21,472.35 hours. To use this distribution in the FMRA, you first select the cause record in the FMRA, double-click inside the **URD** field and click the icon to remove the current reliability definition. Then you double-click inside the **Model** field, select **New Distribution** and create the new distribution shown next. (If the distribution model wizard does not display by default, click the **New Distribution** button or icon, , to get to that page.)



After you click **OK**, the software creates a probability of failure model that uses the distribution you defined, and it assigns this model to the record.



Tip: In this case, you created a model without linking to an analyzed data set. However, if you had access to the data for the corrosion failure mode, you could have used Weibull++ to analyze the data and publish the results as a model. With that approach, if the underlying data analysis ever changes, you have the option to republish the model with updated information and any Synthesis analysis that uses this model would be updated automatically as well.

Finally, you recalculate the FMRA and see that the system's reliability estimate is now 87.79%.

Name	Record Type	Reliability Policy		Reliability (Analytical)
Chandelier	Item	Inherit		0.877936
Frame	Item	Inherit		0.972987
Hold chandelier together	Function	Inherit		0.972987
Frame cracks, fails	Failure	Inherit		0.972987
Corrosion	Cause	Corrosion_URD		0.973036
Metal fatigue due to swinging, cyclical stresses	Cause	Metal fatigue due to swinging, cyclical stresses		0.999950
Wiring	Item	Inherit		0.992525
Bulb and Socket	Item	Inherit		0.909105
Bulb	Item	Inherit		0.932145
Provide light	Function	Inherit		0.932145
Filament burns	Failure	Inherit		0.950990
Filament burns	Cause	Filament burns		0.950990
Bulb shatters	Failure	Inherit		0.990045
Overheat	Cause	Overheat		0.995010
Spike in voltage	Cause	Spike in voltage		0.995010
Base fails to make contact	Failure	Inherit		0.990040
Cap fails to screw all the way	Cause	Cap fails to screw all the way		0.990040
Insufficient Light	Failure	Inherit		1.000000
Bulb wattage too low	Cause	Default (Not Set)		1.000000
Socket	Item	Inherit		0.975283

Updating the Project Plan

Once you finish vetting the FMRA, you can indicate in the project plan that this step of the process has been completed. You choose **Project > Management > Project Planner** so you can update the project plan. You then double-click the **Compute Baseline Reliability** gate, then enter the actual start date of **4/26/2022** and actual completion date of **5/2/2022**. After the update, the plan appears as shown next.

Name	Status	Planned Start Date	Planned Completion Date	Actual Completion Date
Chandelier4 - FMRA Draft		3/1/2022	7/13/2022	
Concept Phase		3/1/2022	3/28/2022	3/21/2022
Requirements & Goals		3/1/2022	3/14/2022	3/10/2022
Environment & Usage		3/15/2022	3/28/2022	3/21/2022
Design Phase		3/29/2022	5/23/2022	
Preliminary Risk Assessment		3/29/2022	4/4/2022	4/4/2022
DFMEA		4/5/2022	4/25/2022	4/25/2022
Compute Baseline Reliability		4/26/2022	5/2/2022	5/2/2022
Reliability Importance Analysis		5/3/2022	5/9/2022	
Reliability Allocation		5/10/2022	5/16/2022	
Update DFMEA		5/17/2022	5/23/2022	

FMRA - Maintenance Planning in RCM++

7

Note: This chapter describes steps for performing calculations that are available only in RCM++ (or RBI).

RCM++ Only

In this chapter

- ✓ Tasks, crews, spare part pools
- ✓ Maintenance costs
- ✓ Availability

The example in Chapter 6 demonstrated how the new failure modes and reliability analysis (FMRA) tool can be used to estimate a system's baseline reliability using whatever is currently known about the probability of occurrence for potential failure modes and/or the reliability of the components. The analysis can continue to be refined and improved over time as better information becomes available. In RCM++ or RBI, the FMRA can also be used to perform simulation-based calculations that take into account the maintenance characteristics of a repairable system.

Specifically, RCM++ uses a Synthesis resource called the *universal reliability definition* (*URD*) to record not only the item's reliability, but also the corrective and preventive maintenance characteristics for repairable components. The software uses this information to simulate the operation of the system for a specified period of operating time in order to calculate a variety of useful metrics, including the reliability, availability and operating costs. This chapter presents an example in which these simulation results are used to estimate the availability and operating costs that can be expected from a specified maintenance strategy for the chandelier. Similar techniques can also be used for comparing different possible maintenance strategies to determine which approach is expected to provide the desired level of availability for the minimum cost.

7.1 Using the FMRA to Estimate Availability and Maintenance Costs

Later in the product life cycle for the chandelier, you are asked to estimate the availability of the system and the maintenance costs that are expected to be incurred by a customer for over two years of use. By this point in time, the team has been able to perform life data analysis and accelerated life data analysis for actual data, and the reliability models for the assemblies/components have been updated accordingly.

Objectives

- Use the FMRA to define all the maintenance tasks for the chandelier's bulb and socket.
- Calculate the chandelier's availability for over 2 years (1,000 hours) of usage, and obtain the maintenance costs that are expected over this time.

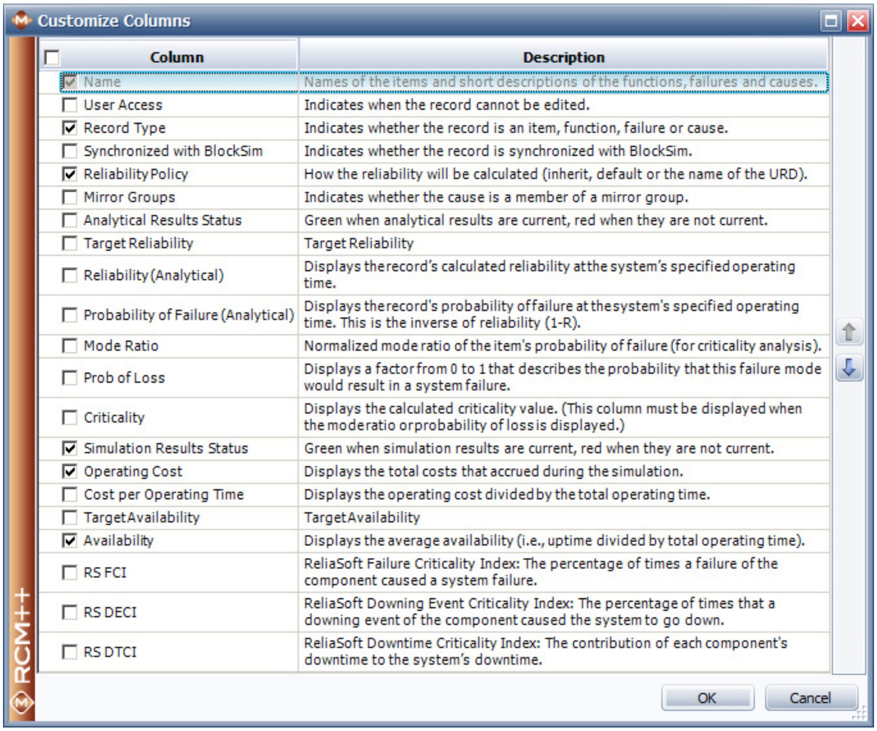
Note: If you want to perform the analysis steps on your own, you will need to start from the "Chandelier6 – FMRA Final" project in the quick start database. This sample project contains new reliability models for the assemblies/components that were not yet available from the prior examples. If you prefer to examine a completed analysis, use "Chandelier7 – FMRA Maintenance."

Solution

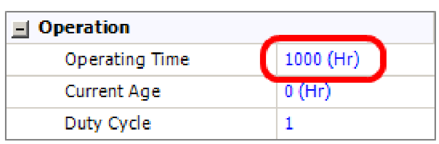
In order to perform the maintainability and availability calculations required for this example, you must use RCM++ or RBI. This functionality is not available in Xfmea.

You open the project and click the **FMRA** tab in the System panel to view all of the items, functions, failures and causes that may impact the system reliability/availability. (If this tab is not already visible on your computer, choose **View > Show > Show FMRA**.)

To select which columns in the FMRA to show on your computer, you right-click a column header in the FMRA and choose **Customize Columns**. For this analysis, you choose to enable only the **Record Type**, **Reliability Policy**, **Simulation Results Status**, **Operating Cost** and **Availability** columns, as shown next. (*Note that you must perform this step even if you are simply examining a completed analysis. These settings are not stored in the database or project.*)



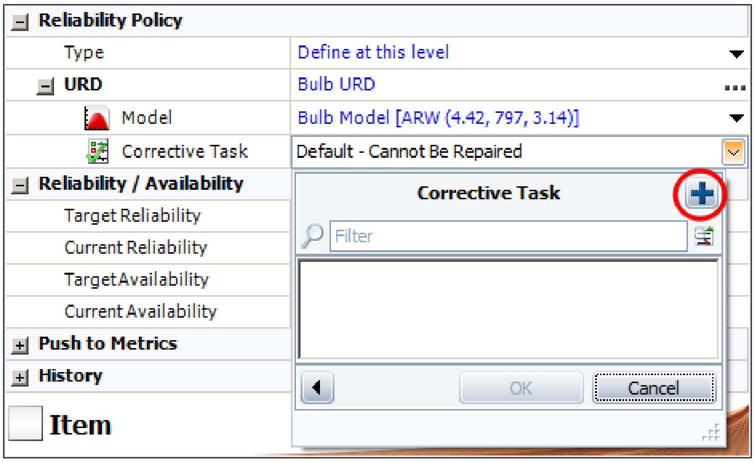
Because you wish to estimate the availability and maintenance costs at 2 years (or 1,000 hours) of operation, you click the chandelier (i.e., top-level system) in the FMRA and enter **1,000** for the **Operating Time** on the Properties tab.



The next step is to define the typical maintenance strategy that you expect most chandelier owners will employ. Specifically, you expect that the owner will replace the bulbs when they burn out, and will hire an electrician for any socket-related failures. No preventive maintenance will be performed.

Defining a New Maintenance Task for the Bulb

To define a corrective maintenance task for the bulb, you need to add a new task resource to the URD that already contains the estimated failure model. To do this, you select the bulb in the FMRA to display its properties in the Analysis panel. You double-click inside the **Corrective Task** field to display a wizard that allows you to either select a task record that has already been defined or create a new one. You click **Create New** as shown next. (*Note that if you're examining the completed analysis, you will only be able to click* ***View/Edit*** *to see the maintenance task properties that have already been defined.*)



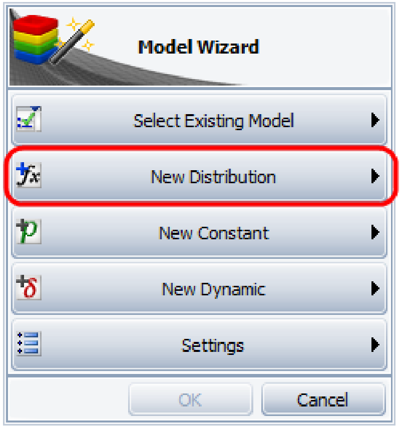
The Maintenance Task window allows you to define the relevant properties that are needed to simulate the typical corrective maintenance strategy for the bulb.

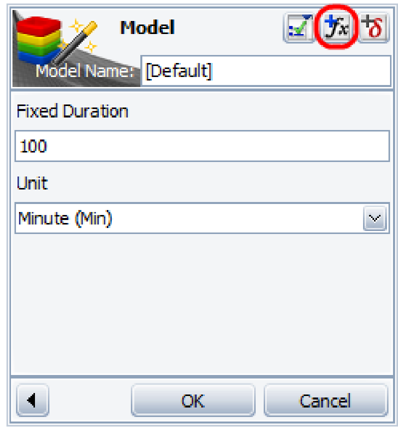
You type "Bulb Replacement" for the **Task Name** and then accept the default option for **Task Scheduling**. The bulb will be replaced when it fails (**Upon item failure**).

You assume that it will take an average of 5 minutes (with a standard deviation of 1 minute) to actually replace the bulb. To model this distribution, you double-click inside the **Task duration** field to open the model wizard. (*If you are examining the completed analysis, you will only be able to click* ***View/Edit*** *to see the model that has already been defined. This window looks different than the model wizard discussed here.*)

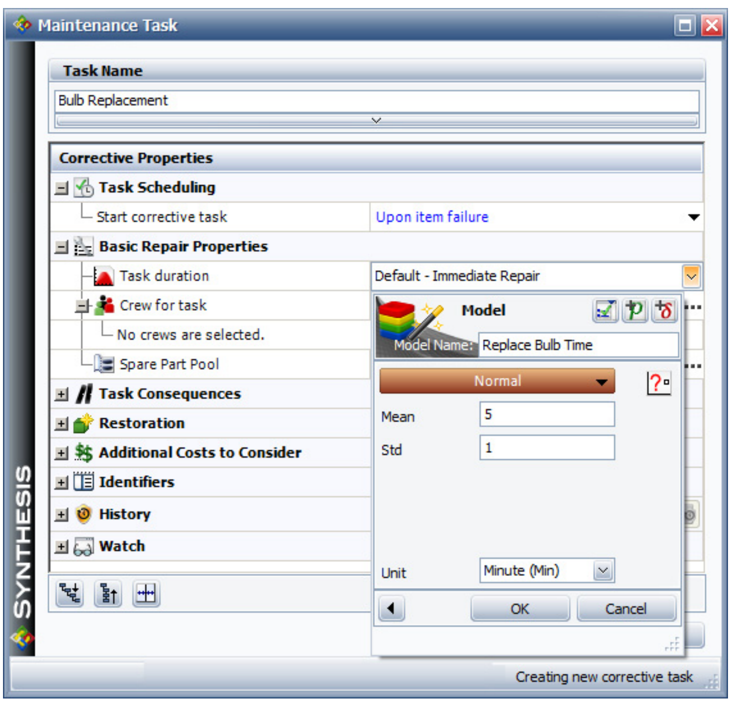
The model wizard provides a variety of different options on different pages. For your convenience, the application "remembers" the page that you used the last time you opened the wizard. If this is not the page you need, you can use the navigation icons to switch to the right one. The following pictures demonstrate how to get to the new distribution page if it doesn't appear by default. If you see the main page, click the

New Distribution button. If you see any other page (select existing new constant by clicking the  icon in the upper right corner).





When you get to the new distribution page, you enter the model name, properties and units, as shown next.



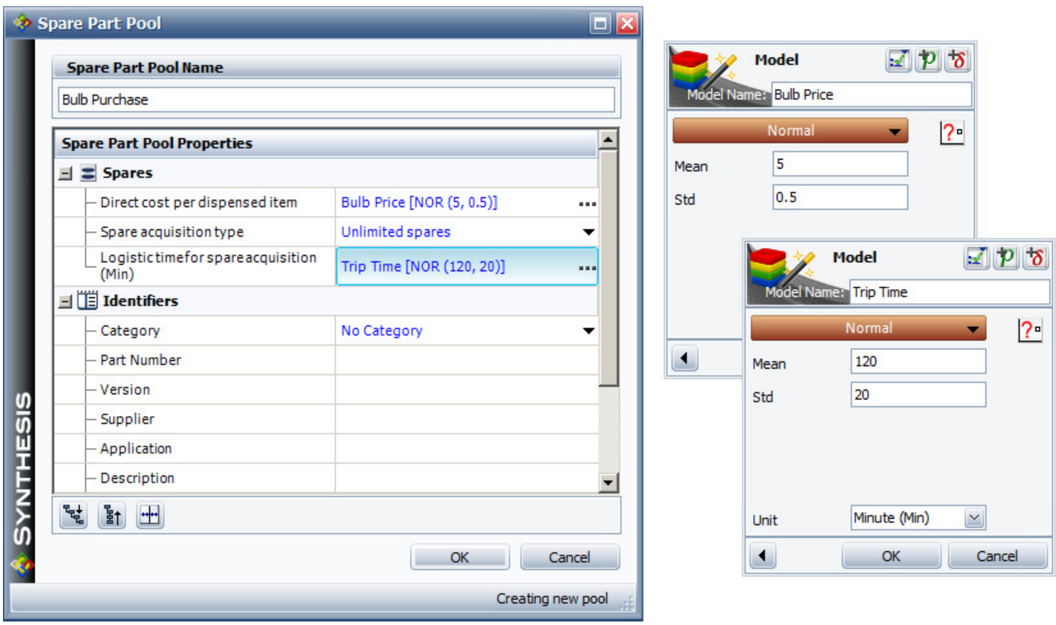
Although the actual replacement only takes an average of 5 minutes, you assume that the owner does not keep spare bulbs on hand and will have to purchase one from a nearby home improvement store.

- The total time for the trip is 2 hours on average (with a standard deviation of 20 minutes).
- The cost for a new bulb is $5 on average (with a standard deviation of $0.50).

So the next step is to create another Synthesis resource that captures the logistics. You double-click inside the **Spare Part Pool** field and click **Create New** +. (*If you are examining the completed analysis, you will only be able to click **View/Edit** to see the properties that have already been defined.*)

In the pool properties window, you type “Bulb Purchase” for the name and then use the model wizard again to create new distributions for the “Bulb Price” ($5 on average with a standard deviation of $0.50) and the “Trip Time” (2 hours on average with a standard deviation of 20 minutes.)

The following pictures show the properties for both models and the final spare part pool properties.

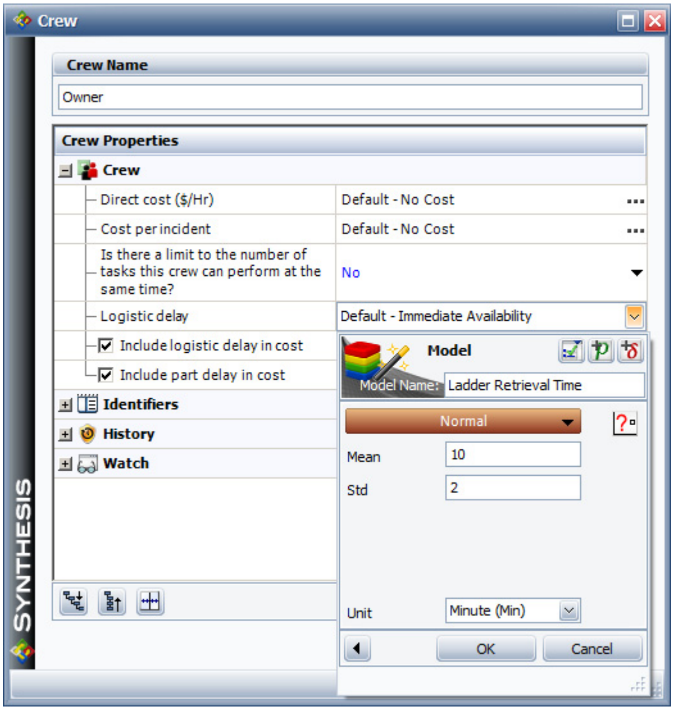


You close the spare part pool window and return to the maintenance task.

Once a spare has been obtained, you assume that the owner will have to use a ladder to reach the failed bulb. On average, it takes 10 minutes (with a standard deviation of 2 minutes) to retrieve and position the ladder.

So the next step is to create another Synthesis resource that captures these logistics. Back on the Maintenance Task window, you double-click inside the **Crew for task** field and click **Create New** +. (*If you are examining the completed analysis, you will only be able to click **View/Edit** to see the properties that have already been defined.*)

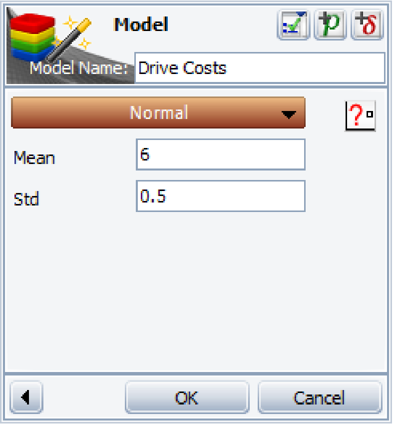
In the crew properties window, you type "Owner" for the name and then double-click inside the **Logistic delay** field. You use the model wizard to create the new distribution for "Ladder Retrieval Time" as shown next.



You save the new model and the new crew resource, then you return to the maintenance task.

Now there is one final cost to consider — the transportation cost (fuel, etc.) from driving to the home improvement store to purchase the bulb. You assume that this is $6 on average (with a standard deviation of $0.50).

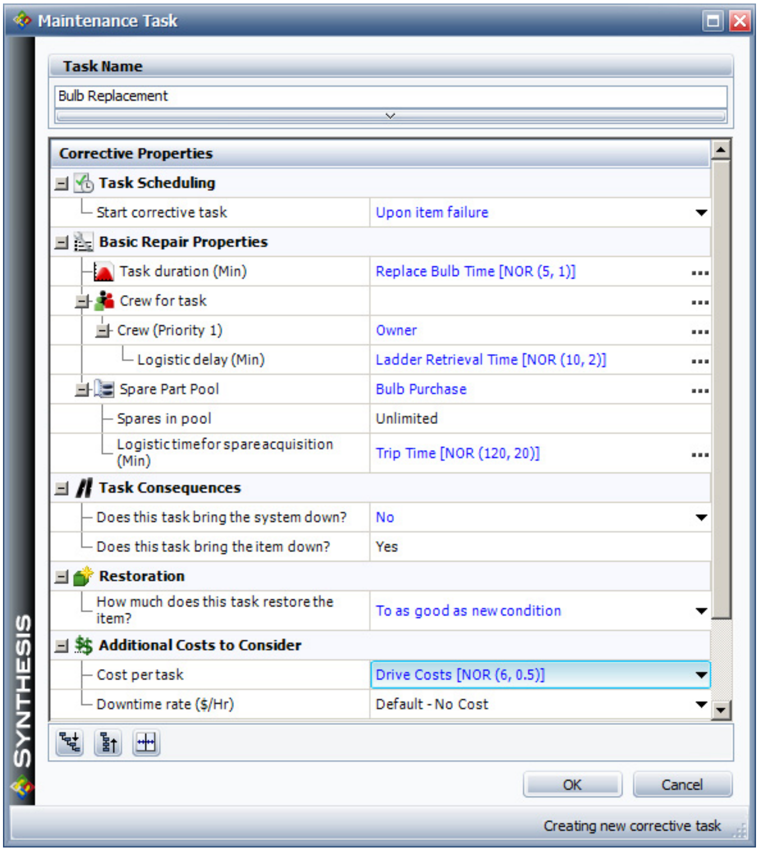
This cost will be defined under the **Additional Costs to Consider** heading in the Maintenance Task window. You double-click inside the **Cost per task** field and create the "Drive Costs" model, as shown next.



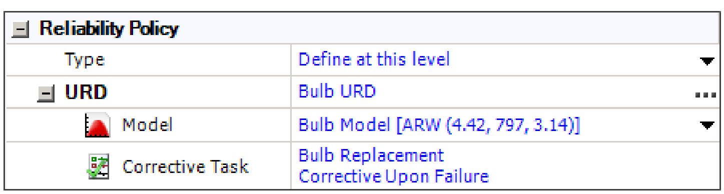
You accept the default settings for all other properties. Specifically:

- For **Task Consequences**, you indicate that replacing the bulb does not require the chandelier to be turned off (i.e., the repair does not bring the system down).
- For **Restoration**, you indicate that the bulb will be "as good as new" after it is replaced.
- The **Downtime rate** is not applicable for this example, so you keep it set to "Default - No Cost."

The complete task properties are shown next.

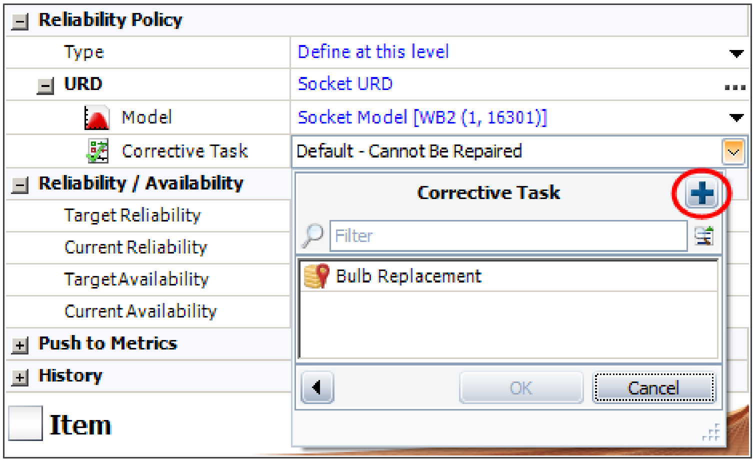


When you save the task and return to the FMRA you can see that the new task is now part of the bulb's reliability policy, as shown next.



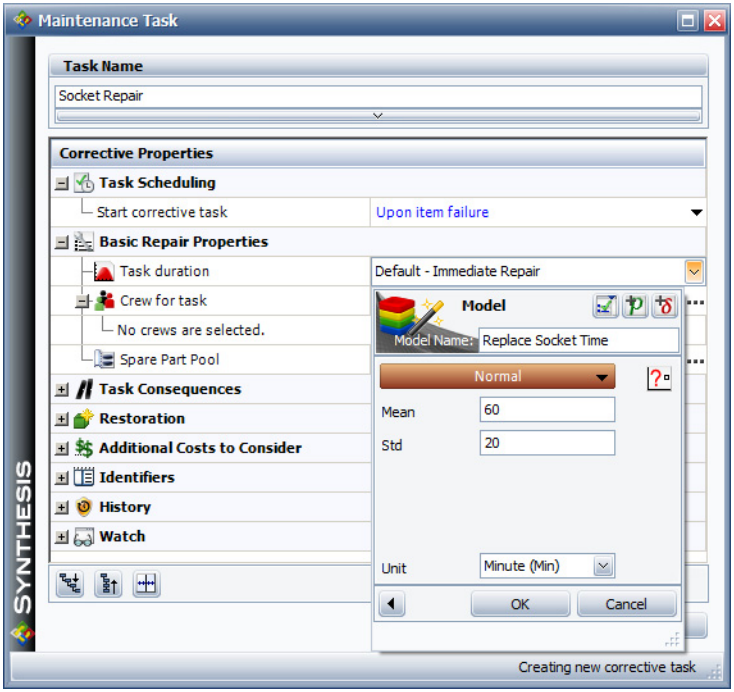
Defining a New Maintenance Task for the Socket

To define a corrective maintenance task for the socket, you first select the socket in the FMRA to display its properties tab in the Analysis panel. Then you double-click inside the **Corrective Task** field to display the wizard, and then click **Create New** + as shown next. (*Note that if you're examining the completed analysis, you will only be able to click **View/Edit** to see the maintenance task properties that have already been defined.*)



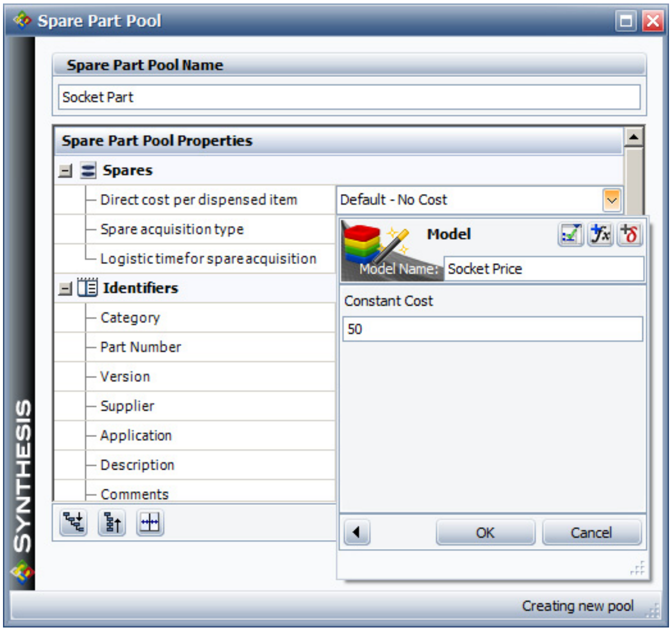
In the Maintenance Task window, you type "Socket Repair" for the **Task Name** and accept the default **Task Scheduling** option: "Upon item failure."

You assume that an electrician will require an average of 1 hour (with a standard deviation of 20 minutes) to actually repair the socket. You double-click inside the **Task duration** field and use the model wizard to create a new distribution, as shown next. (*Remember that you can use the **New Distribution** button or icon to get to the appropriate page of the wizard if it doesn't display by default.*)



Although the actual replacement only takes an average of 60 minutes, you assume that there is a 50% chance that the electrician will have to drive to the home improvement store to purchase the necessary spare part. Either way, you expect that the part will cost $50. To model this, you double-click inside the **Spare Part Pool** field and click **Create New** +. (*If you are examining the completed analysis, you will only be able to click **View/Edit** to see the properties that have already been defined.*)

In the pool properties window, you type “Socket Part” for the name and then double-click inside the **Direct cost per dispensed item** field. This time, you click the **New Constant** button or icon to create a model that contains a single value. You enter the name and value shown next.



You save the new model and return to the pool properties window. Then you click inside the **Spare acquisition type** field and select **Fixed probability of stockout**. This adds some additional rows to the table. You enter **0.5** for the **Fixed probability value**, as shown next. This indicates that there is a 50% chance that the electrician will not have the spare part on hand.

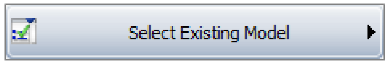
Spares	
Direct cost per dispensed item	Socket Price [50]
Spare acquisition type	Fixed probability of stockout
Fixed probability value	0.5
Logistic time for spare acquisition	Default - Immediate Availability

If the electrician does not have a spare on hand, you assume that he or she will have to take the time to drive to the same home improvement store where the owner would buy spare bulbs.

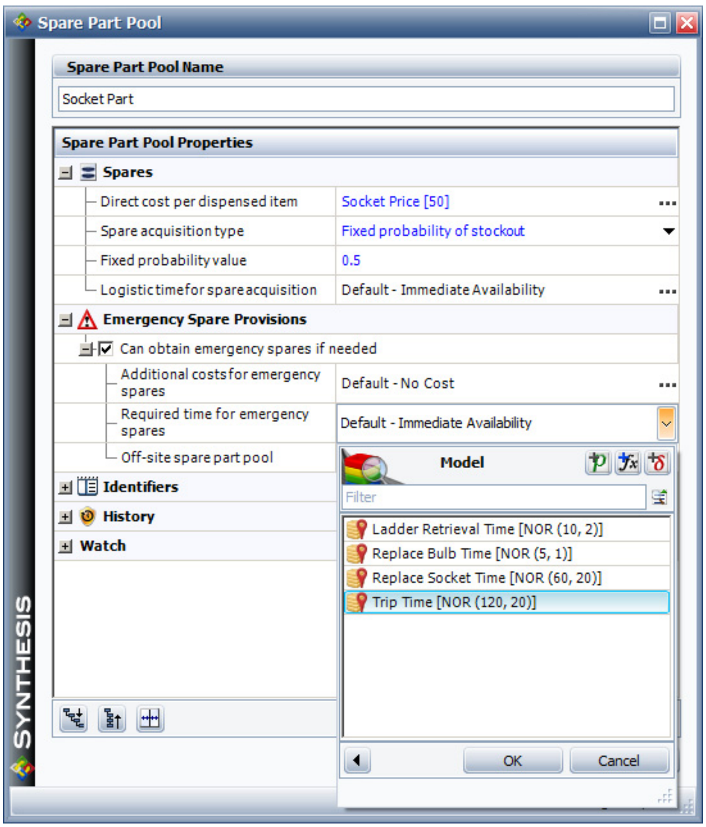
You select the check box under the **Emergency Spare Provision** heading. Once again, this adds some additional rows to the table.

You double-click inside the **Required time for emergency spares** field to open the model wizard again. This time, instead of creating a new model, you want to reuse the same "Trip Time" distribution you used in the bulb replacement task. If the main page of the wizard is not displayed by default, you click the **Back** icon  in the lower-left corner to get to it.

In the main page, you click the **Select Existing Model** button.



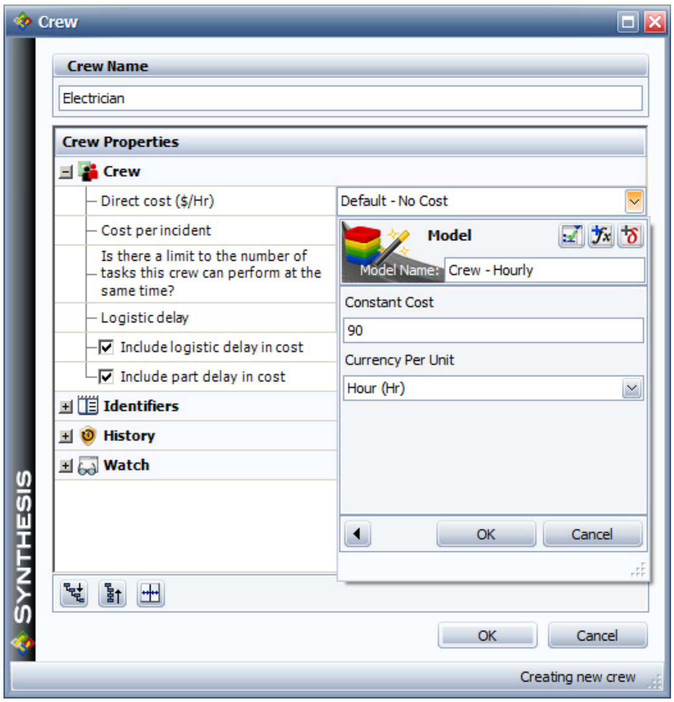
Then you select the existing resource from the list, as shown next.



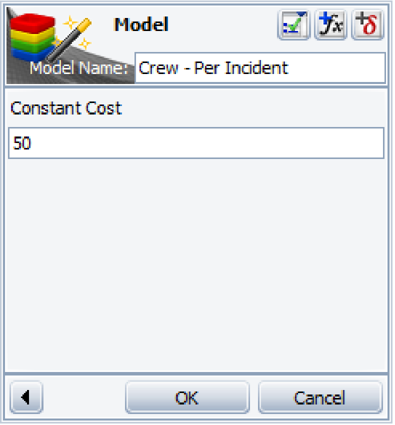
You click **OK** to select the existing model and then click **OK** again to save the new spare part pool.

Back in the Maintenance Task window, the next step is to define a crew resource that indicates how much the electrician charges and how long you'll have to wait for an appointment. You double-click inside the **Crew for task** field and click **Create New** +. (*If you are examining the completed analysis, you will only be able to click **View/Edit** to see the properties that have already been defined.*)

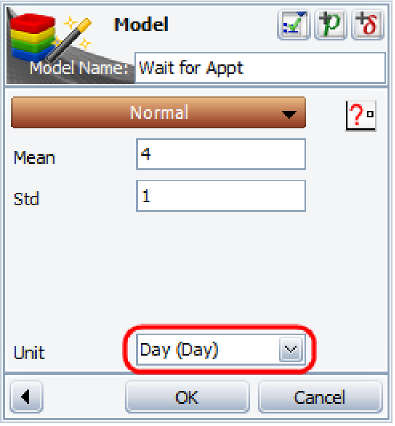
In the crew properties window, you type "Electrician" for the name and then double-click inside the **Direct cost ($/Hr)** field. You assume that the electrician will charge $90 per hour so you create a new constant model for the hourly rate, as shown next.



You also expect a fixed fee of $50 per visit. So you double-click inside the **Cost per incident** field and create another constant model, as shown next.

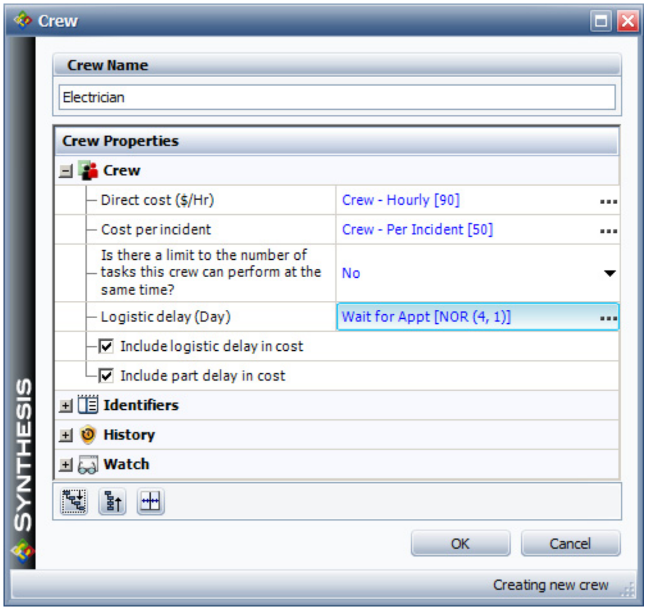


Then you double-click inside the **Logistic delay** field and create a new distribution that reflects the amount of time the owner will have to wait for an appointment. You assume that this will be 4 days on average (with a standard deviation of 1 day). The model properties are shown next. (Note that the time units are now set to Days instead of Minutes.)

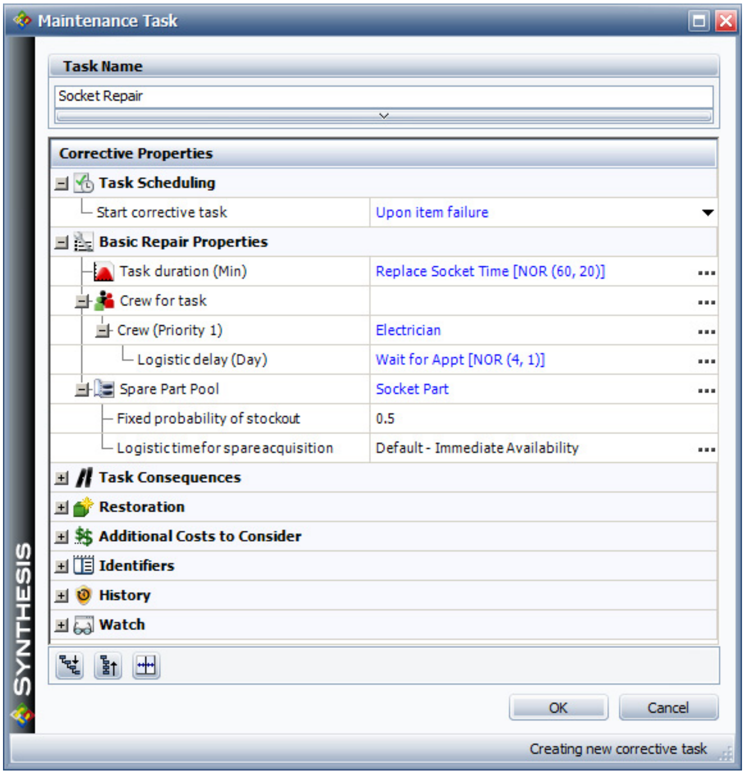


You click **OK** to return to the crew properties window. To ensure that both the time the user spends waiting for the crew (i.e., the logistic delay) and the time spent waiting for the spare parts will be included when calculating the crew costs, you leave the **Include logistic delay in cost** and **Include part delay in cost** options selected.

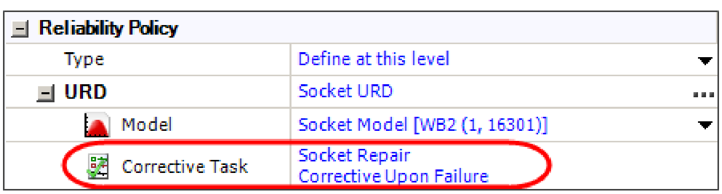
When all of the crew properties have been defined, the window looks like this:



You save the new crew resource and return to the maintenance task. All of the relevant properties are shown next.



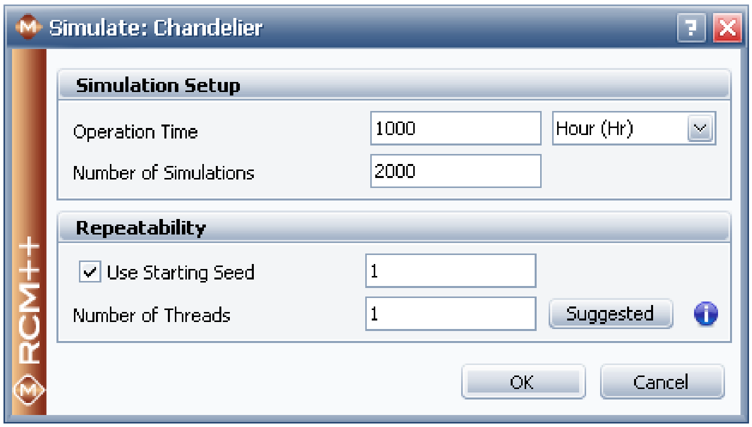
When you save the task and return to the FMRA you can see that the new task is now part of the socket's reliability policy, as shown next.



Estimating the Availability and Maintenance Costs

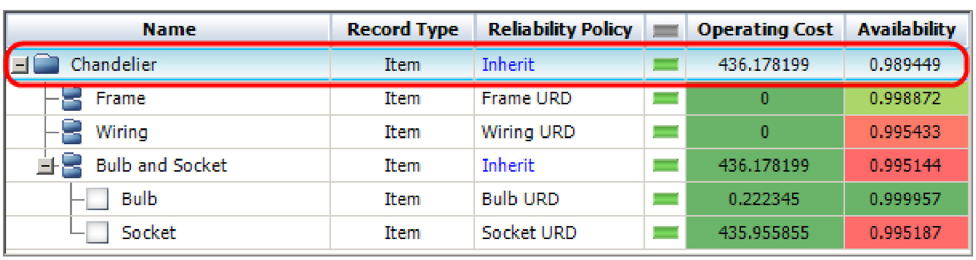
The next step is to use simulation to estimate the availability of the chandelier and the operating costs that are expected over 1,000 hours of operation.

To perform the calculation, you choose **FMRA > Calculations > Simulate (Availability)**. The Simulate window will appear so you can review or edit the options for how the simulation-based values will be obtained. You choose to perform **2,000** simulations, and you select to use a single thread with a starting seed of **1**. (The starting seed will ensure that you get the same result every time you perform the simulation.)



Then you click **OK** to perform the simulation.

You can see that availability values are color-coded using a gradient from red to green (where red is the lowest availability and green is the highest). The FMRA simulation results appear as shown next. (If the color codes are not visible, choose **FMRA > Calculations > Highlight**.)



Name	Record Type	Reliability Policy		Operating Cost	Availability
Chandelier	Item	Inherit		436.178199	0.989449
Frame	Item	Frame URD		0	0.998872
Wiring	Item	Wiring URD		0	0.995433
Bulb and Socket	Item	Inherit		436.178199	0.995144
Bulb	Item	Bulb URD		0.222345	0.999957
Socket	Item	Socket URD		435.955855	0.995187

The total operating cost for the chandelier is expected to be $436.18 over 1,000 hours of operation. Almost all of this is due to costs resulting from the socket's maintenance ($435.96). In addition, the total availability of the chandelier is 98.94%. This means that the chandelier is estimated to be available for about 989 hours during its 1,000 hours of operation (98.94% x 1,000 hours).

Traditional RCM Analysis for a Conveyor Belt

8

> **Note:** This chapter describes the steps for performing a reliability centered maintenance analysis with failure effect categorization and maintenance task selection. This functionality is available only in RCM++ or RBI.

RCM++ Only

In this chapter

- ✓ Equipment selection
- ✓ Functional failure analysis
- ✓ Failure effect categorization
- ✓ Maintenance task selection
- ✓ Reports

Traditional reliability centered maintenance (RCM) analysis provides a structured framework for analyzing the functions and potential failures for a physical asset (such as an airplane, a manufacturing production line, etc.) in order to develop a scheduled maintenance plan that will provide an acceptable level of operability, with an acceptable level of risk, in an efficient and cost-effective manner.

The RCM++ software is shipped with predefined profiles that fit the major published standards and logic diagrams for such analyses (e.g., ATA MSG-3 and SAE JA1011/1012). In general, the analysis methodology described in these standards involves four basic steps: 1) equipment selection, 2) functional failure analysis, 3) failure effect categorization and 4) maintenance task selection.

This chapter shows part of a traditional RCM analysis performed for some of the equipment used to manufacture the chandelier.

8.1 Reliability Centered Maintenance (RCM)

Now that the design for the chandelier is complete and the product has entered production, you begin working with the manufacturing team to assist with process FMEAs (PFMEAs), maintenance planning and other relevant tasks. Your next assignment is to explore the possibility of using traditional RCM analysis techniques to develop effective scheduled maintenance plans for the manufacturing equipment. You begin by conducting a pilot project to perform a simple RCM analysis for a conveyor belt.

Objectives

- Use the equipment selection questions from the SAE JA1012 guidelines to determine whether RCM analysis should be performed for the item.
- Perform a functional failure analysis.
- Use the failure effect categorization (FEC) logic from the SAE JA1012 guidelines to classify the effects of each potential functional failure.
- Use the associated maintenance task selection logic to identify and record the recommended scheduled maintenance tasks.
- Create print-ready reports for the completed analysis.

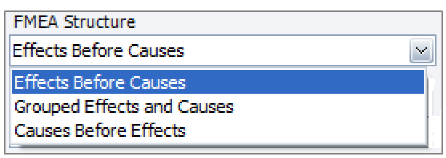
Note: If you want to perform the analysis steps on your own, please create a new project in a new or existing database. This guide provides instructions for recording one branch of the functional failure analysis. If you prefer to examine a completed analysis, you can open the "Conveyor Belt - RCM" project in the quick start database.

Solution

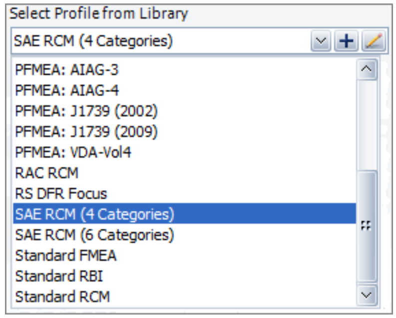
With the database open, you choose **Project > Management > Create Project** and set the project properties that your organization has standardized upon for RCMs.

For the purpose of this example, you can enter anything you wish for the name, description, remarks, proprietary label and project category. Only the project name is required.

You choose **Effects Before Causes** from the **FMEA Structure** drop-down list. As discussed on page 11 in Chapter 3, the software offers a choice of three ways to display the effect and failure mode (cause) records in a functional failure analysis. Your organization uses the **Effects Before Causes** structure because you prefer not to duplicate the effect (and the FEC value) when a functional failure has the same effect regardless of which specific failure mode caused it.

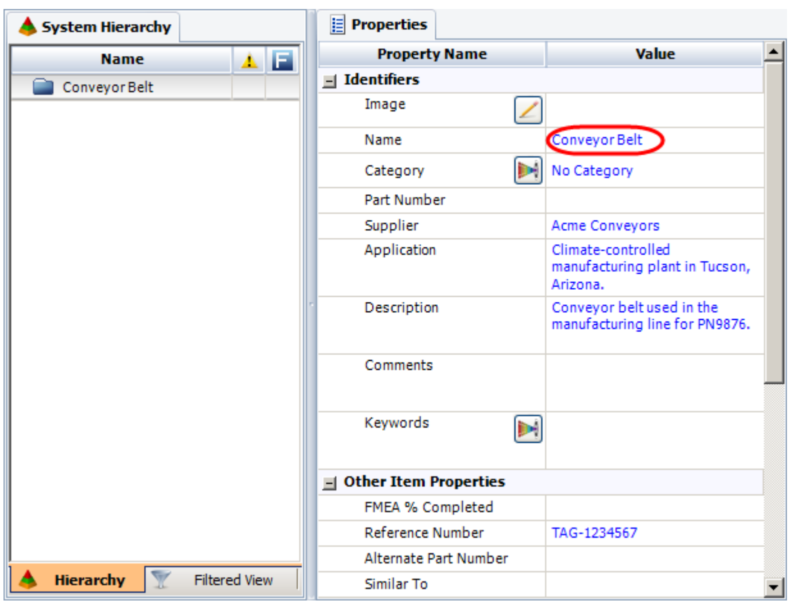


For **Select Profile from Library**, you choose the **SAE RCM (4 Categories)** profile that is shipped with the software by default. This copies the predefined settings (including the RCM logic diagrams) from the active library so they can be used in the current project.

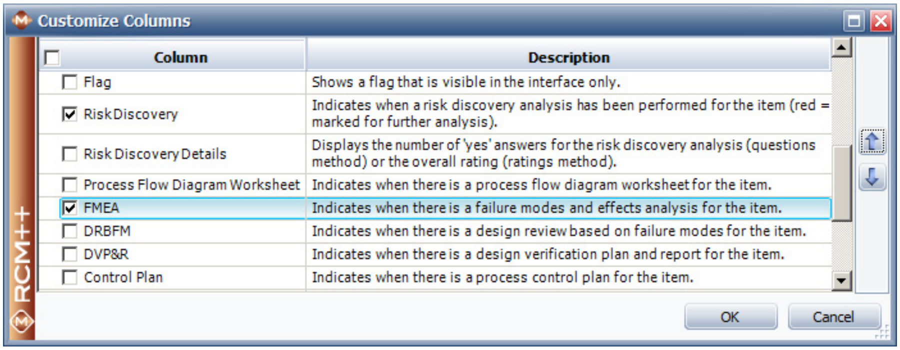


Tip: For your own implementation, it is likely that you (or someone else in your organization) will configure the project categories and profiles library to meet the specific needs of your organization.

When you create a new project, the software automatically adds an item to the system hierarchy. To rename the item to "Conveyor Belt," you select the item and then type inside the **Name** field of the Properties tab. You also enter some additional properties to describe the item, as shown next.



Finally, you right-click one of the system hierarchy column headers and choose **Customize Columns**. For this analysis, you choose to enable only the **Risk Discovery** and **FMEA** columns, as shown next. (*Note that you must perform this step even if you are simply examining a completed analysis. These settings are not stored in the database or project.*)

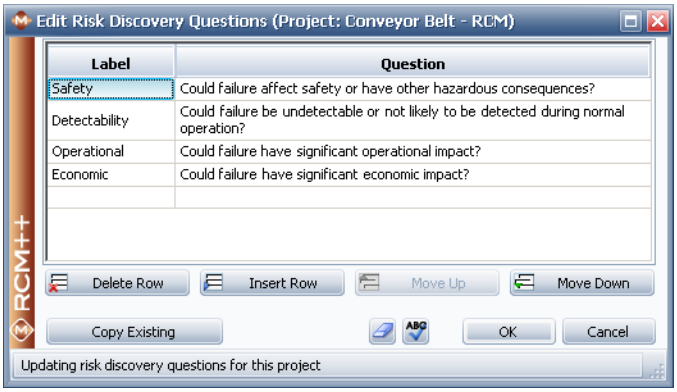


A Note About RCM Terminology: RCM++ combines RCM capabilities and FMEA capabilities together in the same software interface. Although there are many similarities between the two methodologies, there are some basic differences in the terminology and conventions that affect the application interface. Note that:

- **FMEA and Functional Failure Analysis**: Regardless of whether you are performing an RCM analysis or an FMEA, all of the information related to the functions and failure modes will be displayed in the FMEA tab of the Analysis panel, and you will use the commands in the FMEA tab of the ribbon to manage this information. In other words, the term “FMEA” is often used within the software interface in place of “functional failure analysis.”
- **Functional Failures, Failure Modes and Causes**: Although the property names within the software are fully configurable to fit the specific analysis terminology used by your organization, the ribbon commands, icons and window names are not. When a name is not configurable, the term “Failure” is used to refer to the second level in the analysis hierarchy and the term “Cause” is used to refer to the fourth level. If you are performing a functional failure analysis, you might refer to these levels as the “Functional Failure” and “Failure Mode.” If you are performing an FMEA, you might refer to these levels as the “Failure Mode” and “Cause.”

Equipment Selection

When the team convenes for the first meeting, you start by reviewing the criteria that will be used to determine whether RCM should be performed for the item. To see the equipment selection questions that have been defined for this project, you choose **Project > Management > Configurable Settings > RD Questions**. The following picture shows the questions that will be available for any equipment selection analysis performed in this project.

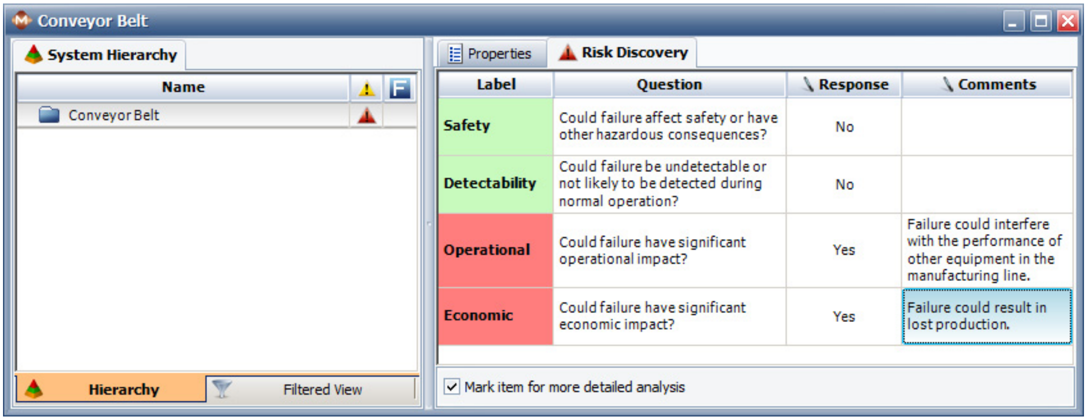


After the team agrees to use these questions without modification, you close the window, then proceed to analyze the conveyor belt. You select the item and choose **Analyses > Planning > Add Risk Discovery**.

The software adds a new **Risk Discovery** tab to the Analysis panel and puts the  icon into the Risk Discovery column of the system hierarchy.

When they consider each of these issues for the conveyor belt, the team answers “yes” to two questions: the conveyor belt’s failure could have an operational effect and there is a potential for a significant economic impact if the conveyor belt breaks. To record this in the risk discovery worksheet, you click the **Response** cells of the **Operational** and **Economic** rows to toggle the answers from “No” (green) to “Yes” (red). As shown in the following picture, you also use the **Comments** field to enter the team’s reasons for answering “yes” to those questions.

Based on these two concerns, the team leaves the **Mark item for more detailed analysis** check box selected and the software displays a red icon in the Risk Discovery column of the system hierarchy.



Functional Failure Analysis

To perform a functional failure analysis on the conveyor belt, you select the item and then choose **Analyses > FMEA > Add FMEA**. The software adds a new **FMEA** tab to the Analysis panel and puts the icon into the FMEA column of the system hierarchy.

The Add Function window displays automatically when you create a new FMEA. You define the primary function of the conveyor belt by typing the following description into the **Function** field:

```
Convey solid material from one location to another at 1000 pounds per
hour while maintaining system integrity and providing feedback to the
distributed control system (DCS)
```

When you click the **Add Failure** button, the software saves the new function record and opens the Add Failure window. You type the following description into the **Functional Failure** field:

```
Conveys no material
```

You then click the **Add Effect** button to open the Add Effect window. You type the following description in the **Effect** field:

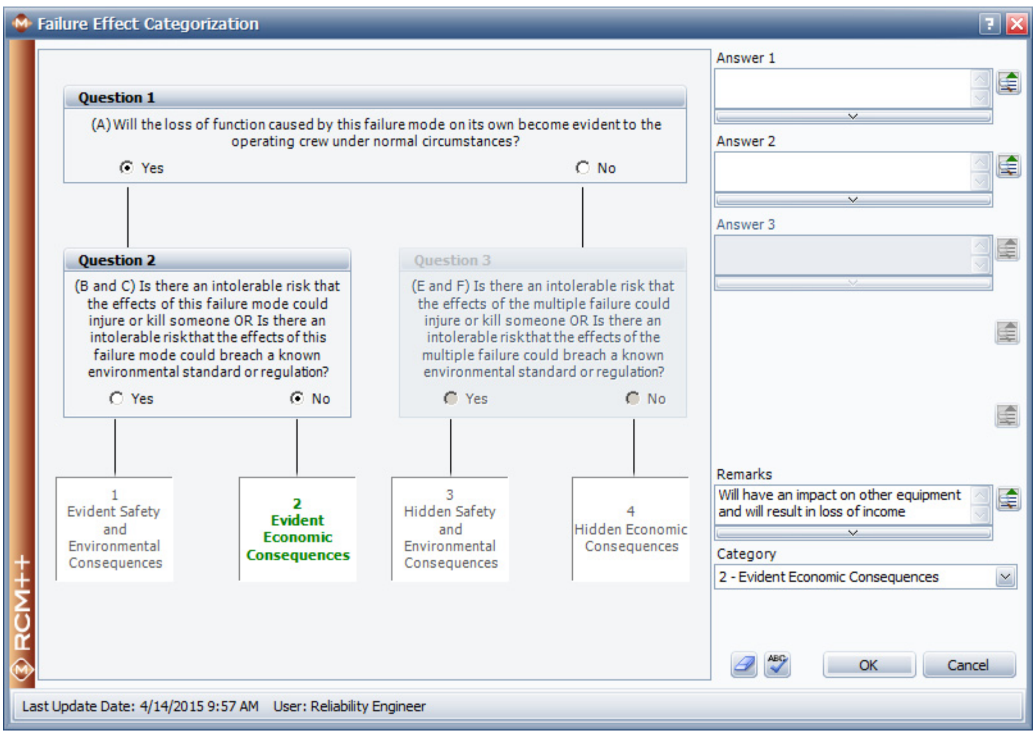
```
Loss of production
```

To perform the failure effect categorization (FEC) for this effect, you click the **Effect Categorization** button.

As shown below, you answer **Yes** to Question 1 and **No** to Question 2. Using these answers, the software automatically categorizes the effect as **2 - Evident Economic Consequences**.

> **Tip:** You can also use the drop-down list in the **Category** field to choose the category directly. In this case, the software automatically sets the answers for you.

Instead of recording the reason for each Yes/No answer, you use the **Remarks** field to record the reason why the team chose this category.



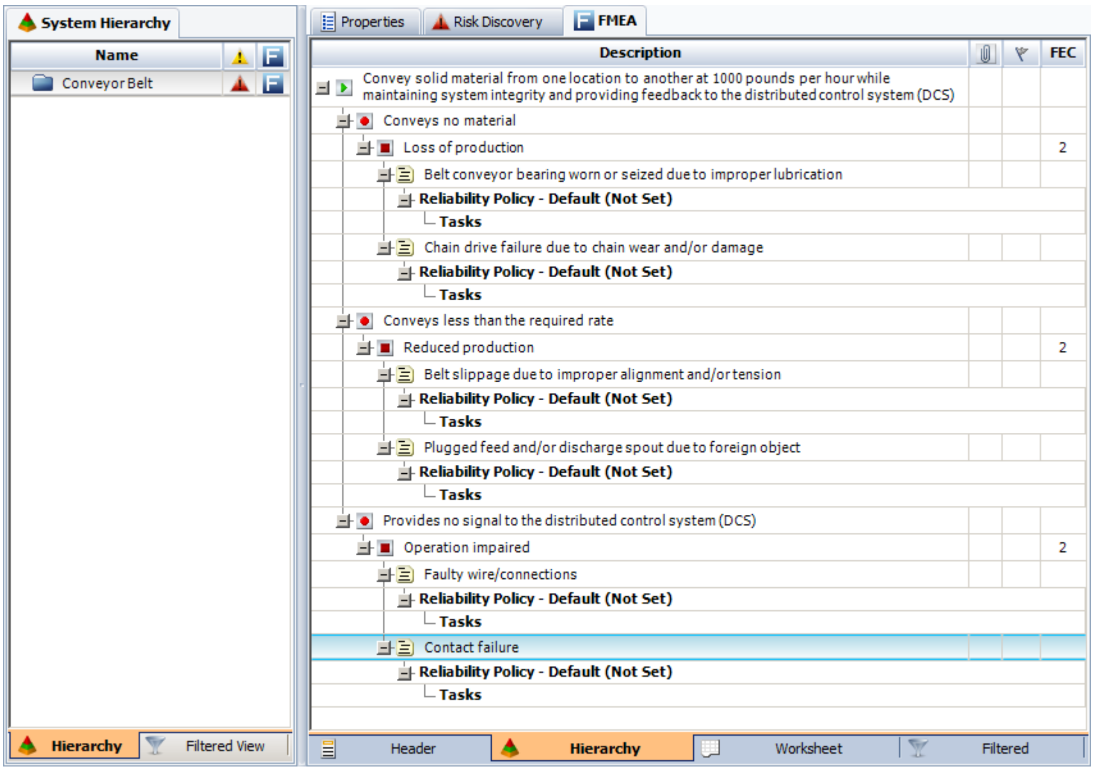
You click **OK** to close the Failure Effect Categorization window, then you click the **Add Cause** button. In the Add Cause window, you type the following description in the **Failure Mode** field:

```
Belt conveyor bearing worn or seized due to improper lubrication
```

You then click the **Add Cause** button again to add a second failure mode and type the following description:

```
Chain drive failure due to chain wear and/or damage
```

You record the rest of the analysis in a similar manner. When completed, the analysis hierarchy will look like the following:

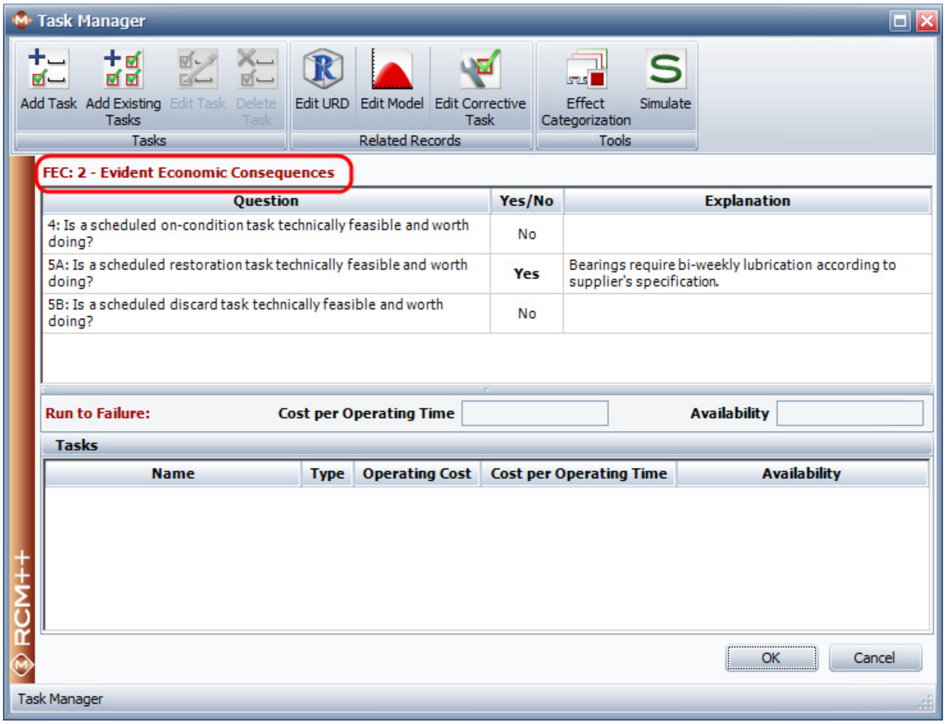


Selecting and Defining a Maintenance Task

When the team is ready to begin working through the maintenance task selection logic, you double-click the **Tasks** node associated with the first failure mode ("Belt conveyor bearing worn or seized due to improper lubrication") to open the Task Manager window.

The FEC value for the effect is displayed under the window's ribbon, along with the task selection questions from the RCM logic that are applicable for effects with "Evident Economic Consequences."

The team determines that an appropriate task is to lubricate the conveyor bearings on a regular basis. To indicate this, you change the answer to question 5A to **Yes** and enter additional comments in the **Explanation** field, as shown next.



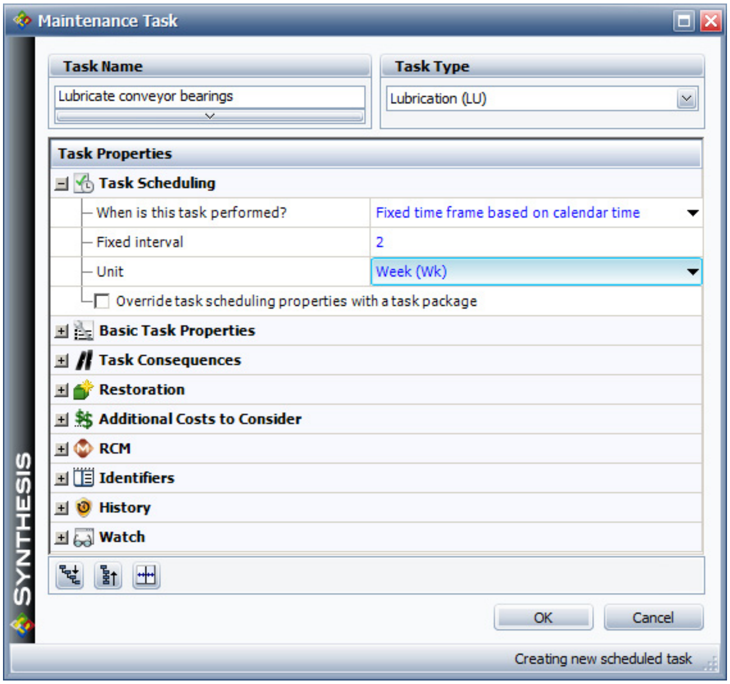
To define a task, you click the **Add Task** button.

In the Maintenance Task window, you do the following:

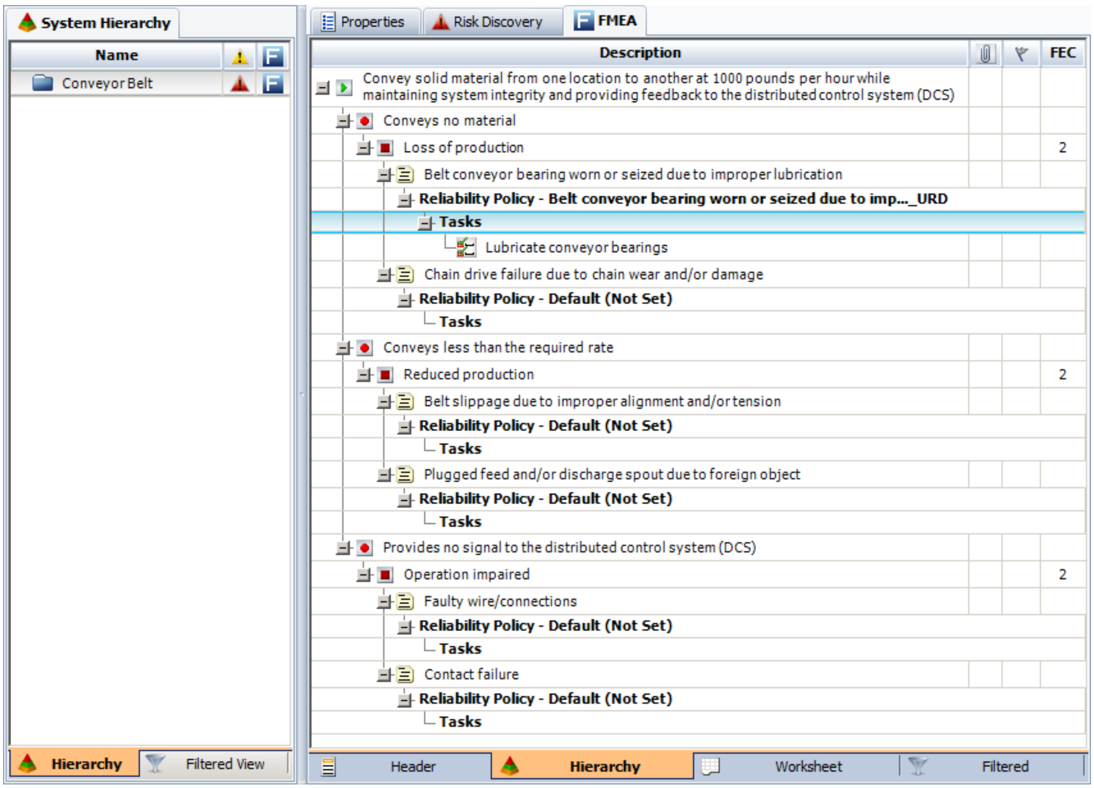
- Enter “Lubricate conveyor bearings” in the **Task Name** field.
- Choose **Lubrication (LU)** from the **Task Type** drop-down list.
- Click the drop-down list in the **Task Scheduling** area and select **At certain intervals**. Click **Based on the calendar time** and then click **OK**. Two new rows appear in the table so you can enter the frequency with which the lubrication task will be performed.

- Enter **2** in the **Fixed Interval** field.
- Choose **Week (Wk)** from the **Unit** drop-down list to set the lubrication interval to 2 weeks.

The Maintenance Task window will look like the following picture:



You then close both the Maintenance Task window and the Task Manager window. The analysis hierarchy looks like the following:



Generating a Report

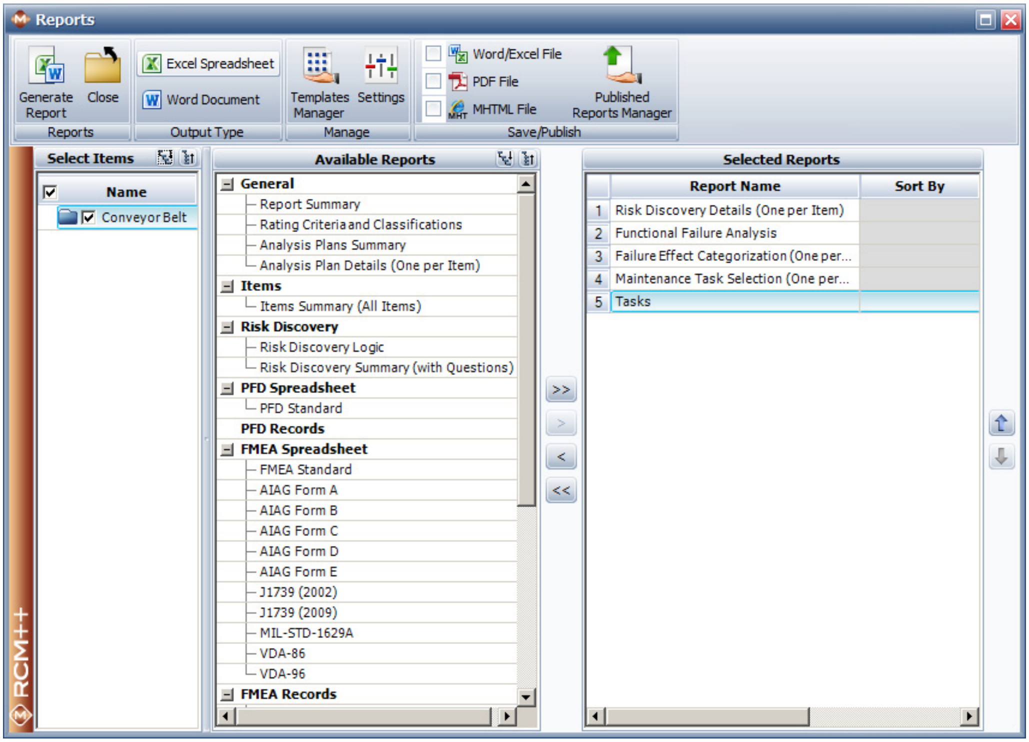
When you are ready to generate a print-ready report that displays the analysis information, you choose **Home > Reporting > Reports**. The Reports window provides a choice of predefined and custom report forms that can be included in a report document generated in either Microsoft Word or Excel.

You first remove any existing reports in the **Selected Reports** area by clicking the **Exclude All** button (<<).

To build the desired report, you double-click, (or drag and drop) the following report forms to move them into the **Selected Reports** area.

- Risk Discovery Details (One per item)
- Functional Failure Analysis

- Failure Effect Categorization (One per Effect)
- Maintenance Task Selection (One per Cause)
- Tasks



You select the **Excel Spreadsheet** option, then click **Generate Report** and specify the name and location where the report file will be saved.

The report will then open automatically in Microsoft Excel. When you are finished reviewing the reports, you close Excel and the Reports windows.

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